COMPREHENSIVE REPORT TO CONGRESS ON PROPOSALS RECEIVED IN RESPONSE TO THE CLEAN COAL TECHNOLOGY PROGRAM OPPORTUNITY NOTICE

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LIST OF EXHIBITS

CHAPTER 1: INTRODUCTION

The vast coal resources of the United States are important assets in meeting the current and future needs of the economy for securely supplied and economical energy. In the future, the role of these resources in providing energy for such uses as electric power generation and industrial applications will undoubtedly increase. However, important issues remain to be resolved regarding increased coal use. In particular, coal use can present important environmental problems. Accordingly, it is essential that coal be used in conjunction with combustion and pollution control technologies that will meet the nation's environmental quality standards.

Over the past 15 years, considerable effort has been directed to developing improved coal combustion, conversion, utilization, and pollution control technologies to provide efficient and economic energy options which will also permit the attainment and maintenance of environmental quality objectives as required by the Clean Air Act and other environmental legislation. In addition to these efforts, the United States Congress made funds available for the Department of Energy (DOE) to undertake a Clean Coal Technology (CCT) program with the objective of conducting cost-shared clean coal technology projects for the construction and operation of facilities to demonstrate the feasibility for their commercial applications.

The Clean Coal Technology program is related to, but not a direct continuation of the effort undertaken by DOE pursuant to Pub. L. No. 98-473. In Pub. L. No. 98-473, An Act Making Continuing Appropriations for the Fiscal Year 1985, and For Other Purposes, Congress directed DOE to solicit expressions of interests in and proposals for, emerging clean coal technology projects and to report to Congress on the statements of interests and proposed projects, the potential usefulness of the technologies for which proposals or expressions of interest were received, and the extent to which Federal incentives would accelerate the commercial availability of the technologies. Later, in anticipation that Congress would provide funds for conducting a CCT program, the conference report accompanying the Supplemental Appropriations Act of 1985 (Pub. L. No. 99-82) urged the Department to begin preparing a competitive solicitation for clean coal technology demonstrations so that fiscal year 1986 funds, if provided, could be obligated in a timely fashion.

In December 1985, Congress made funds available for a CCT program in Pub. L. No. 99-190, An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1986, and for Other Purposes. This Act provided funds "... for the purpose of conducting cost-shared Clean Coal Technology projects for the construction and operation of facilities to demonstrate the feasibility for future commercial applications of such technology..." and authorized DOE to conduct the CCT program. Pub. L. No. 99-190 provided $400 million "... to remain available until expended, of which $100,000,000 shall be immediately available; (2) an additional $150,000,000 shall be available beginning October 1, 1986; (3) an additional $150,000,000 shall be available beginning October 1, 1987." However, section 325 of the Act reduced each amount of budget authority by 0.6 percent, so that these amounts became $99.4 million, $149.1 million, and $149.1 million, respectively, for a total of $397.6 million.

In addition, in the conference report accompanying Pub. L. No. 99-190 the conferees directed DOE to prepare a comprehensive report on the proposals received, after the projects to be funded had been selected. This report fulfills that requirement. Specifically, the report outlines the solicitation process implemented by DOE for receiving proposals for CCT projects, summarizes the project proposals that were received, provides information on the technologies that were the focus of the CCT program, and reviews special issues and topics related to the solicitation.

In response to the Congressional mandate to undertake a CCT program, on February 17, 1986, DOE issued a Program Opportunity Notice (PON) "... to solicit proposals to conduct cost-shared clean coal technology projects to demonstrate the feasibility of these technologies for future commercial applications." In response to the PON, DOE received 51 proposals to design, build, and operate projects to facilitate the efficient, economical, and environmentally acceptable use of U.S. coals in the nation's utility, industrial, and other market sectors. From these proposals, DOE has selected nine projects for award (see Exhibit 1.a).

The PON consisted of 6 sections:

- Section I outlined the departmental objectives in responding to the Congressional mandate
- Section II contained general guidelines for the program
- Section III presented the terms, conditions and other information that would apply to an offeror
- Section IV gave instructions for preparation of a proposal in response to the PON
- Section V described the process for proposal evaluation and the qualification and evaluation criteria as well as program policy factors applicable to the evaluation selection and process

- Section VI presented the policies and guidelines applicable to the Government's financial participation in the CCT projects.

Section II of the PON contained a number of guidelines to enhance the proposer's understanding of the CCT program and to assist in proposal preparation. These guidelines required that the submissions:

1. Be open to all market applications of clean coal technology that apply to any segment of the U. S. coal resource base, including utilities, industry (including steel and iron ore processing), commercial and residential markets, and transportation.

2. Be open to both new and retrofit applications whether intended to displace oil and natural gas or to use coal more cleanly, efficiently, or economically than presently available technology.

3. Consist of industry projects, with financial assistance available from the government at levels up to 50 percent of project cost.

The PON also specified the allocation of Congressionally authorized funds for the CCT program. Of the $397.6 million provided by Congress, $25 million will be held in reserve to cover the cost of overruns in the event that the government agrees to share such costs. In addition, $4.9 million will be redirected to the Small Business and Innovative Research (SBIR) program. Also, funds will be set aside for contracting, travel, and ancillary costs incurred by DOE in implementing the CCT program. If these amounts are allocated by year roughly in proportion to the congressional funding levels, a CCT program budget as shown in Exhibit 1.b results. The major milestones of the solicitation and selection process are shown in Exhibit 1.c.

The remainder of this report contains information on the proposals received and other aspects of the CCT program. Specifically, Chapter 2 of this document provides an overview of the 51 submissions, and Chapter 3 presents a review of special issues and topics related to the PON. The report also contains 2 appendixes. Appendix A contains generic descriptions of the coal technologies for which proposals were received. Appendix B presents summary information on each of the 51 proposals received.

Exhibit 1.a

Clean Coal Projects Selected by the DOE

Proposal No	Sponsor	Technology	Project Location
4	American Electric Power Service Corporation, Columbus, OH	Pressurized Fluidized Bed Combustion Combined Cycle Utility Retrofit	Brilliant, OH
3	Babcock & Wilcox Alliance, OH	Extended Tests of Limestone Injection Multistage Burner Plus the "Coolside" Sorbent Duct Injection Process	Lorain, OH
38	Coal Tech Corp. Merion, PA	Slagging Combustor with Sorbent Injection into Combustor	Williamsport, PA
34	Energy and Environmental Research Corporation Irvine, CA	Gas Reburning & Sorbent Injection retrofit into three utility boilers	Springfield, IL Hennepin, IL Bartonville, IL
20	Energy International, Inc. Cheswick, PA	Steeply Dipping Bed Underground Coal Gasification Integrated with Indirect Liquefaction	Rawlins, WY
48	General Electric Company Cincinnati, OH	Integrated Coal Gasification Steam Injection Gas Turbine Demonstration Plants (2) with Hot Gas Cleanup	Evendale, OH Dunkirk, NY
19	The M.W. Kellogg Company Houston, TX	Fluidized Bed Gas-ification with Hot Gas Cleanup Integrated Combined Cycle Demonstration Plant	Cairnbrook, PA
25	Ohio Ontario Clean Fuels, Inc.	Coal-Oil Coprocessing Liquefaction	Warren, OH
22	Weirton Steel Corporation Weirton, WV	Direct Iron Ore Reduction to Replace Coke Oven/Blast Furnace for Steelmaking	Weirton, WV

Exhibit 1.b

Budget for the Clean Coal Technology Program

	(Thousands of dollars)		
	FY 1986	FY 1987	FY 1988
Congressional Appropriations	$99,400	$149,100	$149,100
Overrun Reserve	6,250	9,375	9,375
SBIR Program	1,226	1,837	1,837
Operating Expenses	1,491	1,988	1,988
Net Monies Available for Award	**$90,433**	**$135,900**	**$135,900**

Exhibit 1.c

Chronology of Major Events

Major Event	Date
Source Selection Official (SSO) Designated	Nov. 15, 1985
Source Evaluation Board (SEB) Constituted	Nov. 19, 1985
Pub. L. No. 99-190 Signed into Law	Dec. 19, 1985
Announcement of PON for Clean Coal Technology Program Published in Federal Register (FR)	Jan. 27, 1986
Announcement of PON Published in Commerce Business Daily	Jan. 28, 1986
Draft PON Issued for Comment	Jan. 30, 1986
Due Date for Public Comments	Feb. 6, 1986
Final PON Issued	Feb. 17, 1986*
Amendment to Final PON Issued	Feb. 24, 1986
Amendment Changing Date and Location of Preproposal Conference Published in FR	Feb. 25, 1986
Preproposal Conference	Mar. 6, 1986
Questions and Answers (Q's & A's) from Preproposal Conference Issued	Mar. 24, 1986
Supplemental Q's & A's Issued	Apr. 9, 1986
Closing Date for Receipt of Proposals	Apr. 18, 1986*
Public Abstracts Released	Apr. 21, 1986
Letters Mailed to Offerors That Failed Preliminary Evaluation	May 16, 1986
SSO Selection	July 24, 1986

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* In accordance with Pub. L. No. 99-190 which provides that the PON be issued "within 60 days following enactment" and that the proposals be submitted "within 60 days after issuance of the general request for proposals."

CHAPTER 2: DESCRIPTION OF SUBMISSIONS

Fifty-one proposals were received in response to the Clean Coal Technology Program Opportunity Notice (PON). Because the PON provided broad flexibility in defining the type of project for which a proposal could be submitted, the proposals exhibit substantial diversity in terms of such dimensions as technologies embraced, project scale, geographic distribution, user sector to which the technology would apply, and type of coal used. The following discussion provides a summary overview of the proposals received in response to the PON. This discussion provides only limited information on the characteristics of specific proposals; the reader is referred to Appendix B for summary descriptions of the individual project submissions.

TECHNOLOGIES PROPOSED

The projects presented in the proposals generally could be assigned to one of nine major technology categories. These categories and the number of proposals received in each category are shown in Exhibit 2.a. The greatest number of proposals received in any category was 10 and involved coal-preparation and waste recovery technologies. In addition, relatively large numbers of proposals were received for the surface coal gasification category (9), atmospheric fluidized-bed combustion (7), and flue gas cleanup (7). Together, these four technology categories account for 33 or nearly two-thirds of the 51 proposals received. Sixteen of the remaining 18 proposals were distributed among, the following technology categories: advanced combustion (4), gasification/fuel cells (3), coal liquefaction (3), industrial processes (3), pressurized fluidized-bed combustion (2), and in-situ (underground) coal gasification (1). The remaining two proposals are listed in the "Other" category. One of these submissions presented a technology (i.e., compressed air storage) that did not fit as part of the identified major categories and the second did not identify a specific technology but endorsed the solicitation goals and the technologies that utilized lime as a processing reagent. Only two of the technologies which were identified in the earlier 1985 request for expression of interest in and proposals for emerging clean coal technologies — magnetohydrodynamics and alternative fuels — were not represented in the submissions received.

Although multiple proposals were received in all but one of the technology categories (in-situ coal gasification), there is considerable diversity in the technological focus of the proposals within the specific technology categories. Exhibit 2.b provides summary information on the specific technological focus for each of the proposals and illustrates the diversity of the projects within the specific technology categories.

PROJECT SCALE

Project scale, as indicated by size and schedule, is another dimension on which the 51 proposals exhibit considerable diversity. The size of projects is indicated by coal processing or energy output capacity. The offerors have proposed projects that range in size from 10 tons per day to 1,450 tons per day of coal feed; 5 MWe to 250 MWe utility power output; 50 kWe to 1.5 MWe fuel cell power output; and 35 tons per day methanol to 11,750 barrels per day of coal-derived distillate. Project schedules also vary considerably, ranging from 12 months to 100 months depending upon the size and number of phases that are included within the scope of the project. More specifically, approximately half of the projects have schedules of 3 to 4 years and three-fourths are scheduled to be completed in 5 years or less. The remaining projects require 6 to 9 years to complete (see Exhibit 2.c).

GEOGRAPHIC DISTRIBUTION

The locations of the proposed projects are substantially concentrated in the coal-producing and coal-using states of the East, North-Central and Mid-Atlantic regions. More than half of the proposed projects (i.e., 28 projects) are located in the four state region of West Virginia, Ohio, Pennsylvania, and Kentucky. Only 11 of the proposed projects are located west of the Mississippi River. Exhibit 2.d indicates the locations of the proposed projects.

MARKET APPLICATIONS

The 51 proposals encompass technologies that would apply to all of the five major energy consumption sectors utilities, industrial, commercial, residential and transportation. However, most of the proposals (i.e., 42) would apply although not exclusively to the electric utility sector, the nation's largest coal consumer. In addition, 31 of the projects would apply to the industrial sector, the next largest coal consuming sector. The combination of projects that would apply to the utility sector, industrial sector, or both, accounts for all of the proposals for which there was adequate information to identify an applicable sector(s). Ten of the proposals indicated potential applicability to the commercial sector. The residential and transportation sectors would each be benefited by four projects. Where projects indicated applicability to sectors that have not traditionally used coal, coal would generally be converted into an alternate fuel (see Exhibit 2.e).

TYPE OF COAL USED BY TECHNOLOGY

The domestic coal resource base exhibits widely varying properties (e.g., sulfur, ash, and volatiles content; heat value; hardness) depending on mining location. Because of the wide variation in coal properties, it is important to understand the breadth of coal types that could be used as feedstocks for the proposed technologies. Consistent with the concentration of projects in the Kentucky, West Virginia, Ohio and Pennsylvania region, all but six of the demonstration projects would use high volatile, bituminous coals characteristic of that region (see Exhibit 2.f). In 8 projects, the use of more than one type of coal is planned. Overall, each of the four types of coal used to characterize the domestic coal resource base was proposed for use in at least one of the projects. In the majority of the projects, the proposer indicated that the commercial version of the process under development would be able to use most U.S. coals as feedstock (see Exhibit 2.g).

COMMERCIALIZATION POTENTIAL

One of the significant requirements of the PON was the need for the submitting organization to discuss the potential of the technology being proposed to become a viable commercial process. Information obtained in this regard included, but was not limited to, the projected date of commercialization, suitable coal feedstocks, scale-up factors from the demonstration to commercial size, projected market, and estimated market penetration by 1995. Some of the data obtained are was summarized by major technology categories with the results shown in Exhibit 2.h.

As shown in this table, it is estimated that all technologies being proposed for development would be ready for commercialization by 1995. Earlier dates are projected for technologies proposed in coal preparation (i.e., 1991) and flue gas clean-up (i.e., 1993). With the exception of in-situ (underground) gasification, the commercial version of each technology would be capable of handling all ranks of coal. Major differences in the technologies were evident, however, when scale-up factors and projected size of market were compared. The range of scale-up factors shown (i.e., from 1-1 or a commercial use of the technology at the scale proposed, to 1-100 in which the commercial size of the project would be 100-times larger than the project proposed) again reflects the variation in stage of development of some of the projects. The projected size of the market and the estimated market penetration are perhaps the most uncertain data presented. The figures should be considered only as order of magnitude estimates that may vary considerably as a function of many market transition factors.

EXHIBIT 2.a

Distribution of Proposals by
Technology Category

TECHNOLOGY CATEGORY	ABBREVIATION	NUMBER OF PROPOSALS
COAL PREPARATION AND WASTE RECOVERY	CP	10
ADVANCED COMBUSTION	ADC	4
FLUIDIZED-BED COMBUSTION		
ATMOSPHERIC FLUIDIZED-BED COMBUSTION	AFB	7
PRESSURIZED FLUIDIZED-BED COMBUSTION	PFB	2
FLUE GAS CLEANUP	FGC	7
SURFACE COAL GASIFICATION	GS	9
GASIFICATION/FUEL CELLS	GFC	3
IN-SITU (UNDERGROUND) COAL GASIFICATION	ISG	1
COAL LIQUEFACTION	LIQ	3
INDUSTRIAL PROCESSES	IND	3
OTHER	-	2
TOTAL		51

EXHIBIT 2.b

Identification of Proposed Processes

CATEGORY	PROPOSAL NUMBER:	PROPOSER	PROCESS IDENTIFICATION
COAL PREPARATION AND WASTE RECOVERY	07	AMERICAN MINERALS, INC.	Coal reclaiming using conventional physical cleaning
	14	NORTH MARION DEV., INC/MADIFCO	Coal reclaiming using conventional and advanced physical cleaning and developmental flotation chemicals
	18	STIRLING ENERGIES INC.	Upgrading coal washing facilities, continous coke making
	24	WESTERN ENERGY COMPANY	Superheated steam drying and physical beneficiation of lignite and sub-bituminous coal
	29	UNITED COAL COMPANY	Coal reclaiming using advanced physical coal cleaning (microbubble flotation)
	32	COMMUNITY CENTRAL ENERGY CORP.	Physical coal cleaning (e.g., dry electrostatics) to prepare coal for industrial boiler
	33	ATLANTIC RESEARCH CORPORATION	Microbial coal cleaning for sulfur and ash removal
	36	COAL TECHNOLOGY CORP.	Coal reclaiming using conventional physical cleaning
	42	MCDONNELL DOUGLAS ENERGY SYS.	Microbubble flotation coal beneficiation
	52	CHEMION CORPORATION	Upgrading of coal quality by chemical extraction of NOx and SOx
ADVANCED COMBUSTION	21	COMBUSTION ENGINEERING, INC.	Combustion characterization of deep physical cleaned coal for utility PC boilers
	23	UNIVERSITY OF FLORIDA	CWM and gas reburning in conventional oil-fired industrial boiler with external combustor
	26	TRW INC.	Slagging combustor w/sorbent injection in boiler
	38	COAL TECH. CORP.	Slagging combustor w/sorbent injection in combustor
ATMOSPHERIC FLUIDIZED-BED COMBUSTION	08	CITY OF TALLAHASSEE	Circulating AFB utility retrofit
	10	UNIVERSITY OF CINCINNATI	Modified (swirling flow) circulating AFB for industrial steam
	12	ENERGOTECHNOLOGY CORP.	Coal cleaning coupled w/AFB retrofit to conventional PC boiler
	13	COLORADO-UTE ELECTRIC ASSOC.	Circulating AFB utility retrofit
	27	COMMUNITY CENTRAL ENERGY CORP.	Anthracite-culm fired AFB for industrial steam
	35	CURATORS/UNIV. OF MISSOURI	Bubbling AFB w/multisolids bed for industrial steam
	39	SOUTHWEST PUBLIC SERV. CO.	Circulating AFB utility retrofit

EXHIBIT 2.b, cont.

Identification of Proposed Processes

CATEGORY	PROPOSAL NUMBER:	PROPOSER	PROCESS IDENTIFICATION
PRESSURIZED FLUIDIZED-BED COMBUSTION	04	AMERICAN ELECTRIC POWER SERV.	PFB combined cycle utility retrofit
	11	WISCONSIN ELECTRIC POWER CO.	PFB turbocharged cycle utility retrofit
FLUE GAS CLEANUP	03	THE BABCOCK & WILCOX COMPANY	LIMB extension and "coolside" sorbent duct injection
	17	NOXSO CORPORATION	Dry simultaneous NOx and SOx absorption
	34	ENERGY & ENVIRONMENTAL RES. CORP.	Gas reburning and sorbent injection retrofit to utility boiler
	40	RECOVERY SYSTEMS LIMITED	Combined NOx and SOx removal with a phospate by-product
	45	TENNESSEE VALLEY AUTHORITY	Lime spray dryer/baghouse on eastern coal-fired boiler
	49	FMC CORPORATION	NOx and SO2 removal by injection of dry sodium compounds
	53	CHARWILL CORPORATION	NOx and SOx reduction by wet scrubbing of stack gases with a borate solution
GASIFICATION	01	ELGIN BUTLER BRICK CO.	Integration of four clean coal technologies for power generation
	05	PENNSYLVANIA COAL TECH. INC.	Clean gas for power generation from coke production gases
	06	CONSOL-FW	Fluid-bed gasifier, hot gas cleanup integrated combined cycle system
	09	CALDERON ENERGY COMPANY	Fixed-bed coking/gasification for fuel gas production and hot gas cleanup combined cycle
	19	THE M.W. KELLOGG COMPANY	Fluid-bed gasifier, hot gas cleanup integrated combined cycle system
	30	DRAVO WELLMAN CO.	Clean low-Btu fuel gas from coal
	31	SANITECH, INC.	Moving grate gasifier for fuel gas production
	46	QUESTAR SYNFUELS CORPORATION	Entrained-bed gasifier w/cold cleanup for fuel gas and methanol production
	48	GENERAL ELECTRIC COMPANY	Fixed-bed gasifier, hot gas cleanup with advanced turbine for electricity production

EXHIBIT 2.b, cont.

Identification of Proposed Processes

CATEGORY	PROPOSAL NUMBER:	PROPOSER	PROCESS IDENTIFICATION
GASIFICATION/ FUEL CELLS	37	ZTEC CORPORATION	Solid oxide zirconia fuel cell for eventual integration into coal gasifiers
	41	PPG INDUSTRIES	Phosphoric acid fuel cell fueled by hydrogen
	43	WESTINGHOUSE ELECTRIC CORP.	Phosphoric acid fuel cell coupled w/coal-derived fuel gas
IN-SITU GASIFICATION	20	ENERGY INTERNATIONAL, INC.	Steeply-dipping bed underground gasification integrated w/indirect liquefaction
LIQUEFACTION	25	OHIO ONTARIO CLEAN FUELS INC.	Coal-oil co-processing to produce refinery products
	44	CHEMCOAL ASSOCIATES	Coal liquefaction under mild catalytic conditions using phenolic solvent
	47	TENNESSEE VALLEY AUTHORITY	Entrained-bed gasifier w/cold cleanup coupled with liquid-phase methanol production for peaking
INDUSTRIAL PROCESSES	02	STATE OF MINNESOTA	Direct iron ore reduction to replace coke oven/blast furnace
	16	DOW CORNING CORPORATION	Waste energy and byproduct recovery
	22	WEIRTON STEEL CORPORATION	Direct iron ore reduction to replace coke oven/blast furnace
OTHER	15	CLEVELAND ELEC. ILLUMINATING CO.	Compressed air energy storage for electric utility peaking power
	51	NATIONAL LIME ASSOCIATION	General support of technologies utilizing lime

EXHIBIT 2.c

Project Scale: Size and Schedule

TECHNOLOGY	PROPOSAL NUMBER	PROPOSER	CAPACITY	START DATE	END DATE	DURATION (MONTHS)
COAL PREPARATION AND WASTE RECOVERY	07	AMERICAN MINERALS INC.	1600 TPD FEED 400 TPD PRODUCT	9/30/86	9/30/93	84
	14	NORTH MARION DEVELOPMENT INC.	30-60 TPH	9/1/86	9/1/89	36
	18	STIRLING ENERGIES INC.	NOT SPECIFIED	8/1/86	8/1/93	84
	24	WESTERN ENERGY CO.	50 TPH	3/1/87	3/1/89	24
	29	UNITED COAL CO.	PROPRIETARY	10/1/86	10/1/88	24
	32	COMMUNITY CENTRAL ENERGY INC.	5 TPH	1/1/87	3/1/89	26
	33	ATLANTIC RESEARCH CORP.	24 TPD	9/1/86	5/1/88	20
	36	COAL TECHNOLOGY CORP.	1000 TPD	6/30/86	2/29/88	20
	42	MCDONNELL DOUGLAS ENERGY SYS. INC.	5 TPH	10/1/86	7/1/90	45
	52	CHEMION CORP.	5 TPH	8/15/86	8/15/86	24
ADVANCED COMBUSTION	21	COMBUSTION ENGINEERING	20 TPH	10/1/86	10/1/89	36
	23	UNIVERSITY OF FLORIDA	10 TPH	9/1/86	9/1/89	36
	26	TRW INC.	69 MWe	10/1/87	10/1/90	36
	38	COAL TECH CORP	1 TPH	10/1/86	1/1/89	27
ATMOSPHERIC FLUIDIZED-BED COMBUSTION	08	CITY OF TALLAHASSEE	250 MWe	10/1/86	2/1/91	52
	10	UNIVERSITY OF CINCINNATI	100,000 LBS/ HR STEAM	8/11/86	8/11/89	36
	12	ENERGOTECHNOLOGY CORP.	60 TPH	9/30/86	9/30/91	60
	13	COLORADO-UTE ELECTRIC ASSOCIATION	110 MWe	9/1/86	2/1/90	40
	27	COMMUNITY CENTRAL ENERGY CORP.	130 TPD CULM	10/1/86	10/1/89	36
	35	UNIVERSITY OF MISSOURI	200,000 LBS/ HR STEAM	10/1/86	10/1/87	12
	39	SOUTHWESTERN PUBLIC SERVICE CORP.	250 MWe	8/1/86	1/1/95	100

EXHIBIT 2.c, cont.

Project Scale: Size and Schedule

TECHNOLOGY	PROPOSAL NUMBER	PROPOSER	CAPACITY	START DATE	END DATE	DURATION (MONTHS)
PRESSURIZED FLUIDIZED-BED COMBUSTION	04	AMERICAN ELEC. POWER SERV. CORP.	70 MWe	4/30/86	8/30/92	76
	11	WISCONSIN ELECTRIC POWER CO.	80 MWe	9/1/86	9/1/94	84
FLUE GAS CLEANUP	03	BABCOCK AND WILCOX COMPANY	105 MWe	9/1/86	4/1/90	43
	17	NOXSO CORP.	5 MWe	10/1/86	10/1/88	24
	34	ENERGY & ENVIRONMENTAL RESEARCH	117, 80, 40 MWe	1/1/87	1/1/91	48
	40	RECOVERY SYSTEMS LIMITED	100 MWe	1/2/87	3/2/90	38
	45	TENNESSEE VALLEY AUTHORITY	160 MWe	1/1/87	12/1/90	47
	49	FMC CORPORATION	100 MWe	NOT GIVEN	NOT GIVEN	2
	53	CHARWILL CORPORATION	NOT GIVEN	NOT GIVEN	NOT GIVEN	NOT GIVEN
GASIFICATION	01	ELGIN-BUTLER BRICK CO.	5,000 DSCFM GAS 750 LBS/ HR DISTILLATE	GO AHEAD		42
	05	PENNSYLVANIA COAL TECH. INC.	200,000 TPY COKE 13 MWe	9/15/86	7/15/90	45
	06	CONSOL/FOSTER WHEELER	30 MWe 200,000 LBS/ HR STEAM	1/1/87	1/1/90	36
	09	CALDERON ENERGY CO.	50 MWe	6/1/86	6/1/92	72
	19	M. W. KELLOG CO.	60 MWe	10/1/86	1/1/90	63
	30	DRAVO WELLMAN CO.	70 MM BTU/HR	9/1/86	4/1/90	42
	31	SANITECH INC.	100 MM BTU/HR	10/1/86	10/1/89	36
	46	QUESTAR SYNFUELS CORP.	30 TPD	7/1/86	7/1/90	48
	48	GENERAL ELECTRIC CO.	50 MWe; 5 MWe	1/2/87	1/2/92	60

T	END DATE	DURATION (MONTHS)
	1992	72

EXHIBIT 2.d

Geographic Distribution of Proposers and Projects

TECHNOLOGY	PROPOSAL NUMBER	PROPOSER	PROPOSERS LOCATION STATE	------PROJECT LOCATION------ STATE	COUNTY
COAL PREPARATION AND WASTE RECOVERY	07	AMERICAN MINERALS INC.	KANSAS	KANSAS	OSWEGO
	14	NORTH MARION DEVELOPMENT INC.	WEST VIRGINIA	WEST VIRGINIA	MARION
	18	STIRLING ENGINES INC.	WEST VIRGINIA	WEST VIRGINIA	RALEIGH
	24	WESTERN ENERGY CO.	MONTANA	MONTANA	ROSEBUD
	29	UNITED COAL CO.	VIRGINIA	WEST VIRGINIA	LOGAN
	32	COMMUNITY CENTRAL ENERGY INC.	PENNSYLVANIA	PENNSYLVANIA	LACKAWANNA
	33	ATLANTIC RESEARCH CORP.	VIRGINIA	PROPRIETARY	PROPRIETARY
	36	COAL TECHNOLOGY CORP.	FLORIDA	PENNSYLVANIA	FEYETTE
	42	MCDONNELL DOUGLAS ENERGY SYS. INC.	KENTUCKY	KENTUCKY	SHELBY
	52	CHEMION CORP.	NEVADA	NOT DETERMINED	NOT DETERMINED
ADVANCED COMBUSTION	21	COMBUSTION ENGINEERING	CONNECTICUT	PENNSYLVANIA	INDIANA
	23	UNIVERSITY OF FLORIDA	FLORIDA	FLORIDA	ALACHOA
	26	TRW INC.	CALIFORNIA	NEW YORK	ROCKLAND
	38	COAL TECH CORP	PENNSYLVANIA	PENNSYLVANIA	LYCOMING
ATMOSPHERIC FLUIDIZED-BED COMBUSTION	08	CITY OF TALLAHASSEE	FLORIDA	FLORIDA	LEOH
	10	UNIVERSITY OF CINCINNATI	OHIO	OHIO	HAMILTON
	12	ENERGOTECHNOLOGY CORP.	MASSACHUSETTS	NORTH CAROLINA	ROCKINGHAM
	13	COLORADO-UTE ELECTRIC ASSOCIATION	COLORADO	COLORADO	MONTROSE
	27	COMMUNITY CENTRAL ENERGY CORP.	PENNSYLVANIA	PENNSYLVANIA	LACKAWANNA
	35	UNIVERSITY OF MISSOURI	MISSOURI	MISSOURI	BOONE
	39	SOUTHWESTERN PUBLIC SERVICE CORP.	TEXAS	TEXAS	POTTER

EXHIBIT 2.d, cont.

Geographic Distribution of Proposers and Projects

TECHNOLOGY	PROPOSAL NUMBER	PROPOSER	PROPOSERS LOCATION STATE	------PROJECT LOCATION------ STATE	COUNTY
PRESSURIZED FLUIDIZED-BED COMBUSTION	04	AMERICAN ELEC. POWER SERV. CORP.	OHIO	OHIO	JEFFERSON
	11	WISCONSIN ELECTRIC POWER CO.	WISCONSIN	WISCONSIN	OZAUKEE
FLUE GAS CLEANUP	03	BABCOCK AND WILCOX INC.	OHIO	OHIO	LORAIN
	17	NOXSO CORP.	PENNSYLVANIA	OHIO	JEFFERSON
	34	ENERGY & ENVIRONMENTAL RESEARCH	CALIFORNIA	ILLINOIS	PEORIA
	40	RECOVERY SYSTEMS LIMITED	ILLINOIS	NOT DETERMINED	NOT DETERMINED
	45	TENNESSEE VALLEY AUTHORITY	TENNESSEE	KENTUCKY	MCCRACKEN
	49	FMC CORPORATION	ILLINOIS	OHIO	CLERMONT
	53	CHARWILL CORPORATION	CALIFORNIA	NOT GIVEN	NOT GIVEN
GASIFICATION	01	ELGIN-BUTLER BRICK CO.	TEXAS	TEXAS	BASTROP
	05	PENNSYLVANIA COAL TECH. INC.	PENNSYLVANIA	NOT DETERMINED	NOT DETERMINED
	06	CONSOL/FOSTER WHEELER	PENNSYLVANIA	WEST VIRGINIA	MONONGAHELIA
	09	CALDERON ENERGY CO.	OHIO	OHIO	WOOD
	19	M. W. KELLOG CO.	TEXAS	PENNSYLVANIA	SOMERSET
	30	DRAVO WELLMAN CO.	PENNSYLVANIA	NOT DETERMINED	NOT DETERMINED
	31	SANITECH INC.	OHIO	OHIO	BULTER
	46	QUESTAR SYNFUELS CORP.	UTAH	UTAH	SALT LAKE
	48	GENERAL ELECTRIC CO.	OHIO	OHIO	HAMILTON
				NEW YORK	CHAUTAUQUA
GASIFICATION/ FUEL CELLS	37	ZTEC CORPORATION	MASSACHUSETTS	NOT DETERMINED	NOT DETERMINED
	41	PPG INDUSTRIES	LOUISIANA	LOUISIANA	CALCASIEV
	43	WESTINGHOUSE ELECTRIC CORP.	PENNSYLVANIA	PENNSYLVANIA	WESTMORELAND

EXHIBIT 2.d, cont.

Geographic Distribution of Proposers and Projects

TECHNOLOGY	PROPOSAL NUMBER	PROPOSER	PROPOSERS LOCATION STATE	------PROJECT LOCATION------ STATE	COUNTY
IN-SITU GASIFICATION	20	ENERGY INTERNATIONAL, INC.	PENNSYLVANIA	WYOMING	CARSON
LIQUEFACTION	25	OHIO ONTARIO CLEAN FUELS INC.	OHIO	OHIO	TROMBULL
	44	CHEMCOAL ASSOCIATES	OHIO	OHIO	MONROE
	47	TENNESSEE VALLEY AUTHORITY	ALABAMA	ALABAMA	COLBERT
INDUSTRIAL PROCESSES	02	STATE OF MINNESOTA	MINNESOTA	MINNESOTA	ST. LOUIS
	16	DOW CORNING CORPORATION	MICHIGAN	WEST VIRGINIA	MASON
	22	WEIRTON STEEL CORPORATION	WEST VIRGINIA	WEST VIRGINIA	HANCOCK
OTHER	15	CLEVELAND ELEC. ILLUMINATING CO.	OHIO	NOT DETERMINED	NOT DETERMINED
	51	NATIONAL LIME ASSOCIATION	VIRGINIA	NOT DETERMINED	NOT DETERMINED

EXHIBIT 2.e

Application of Projects to Energy-Consuming Sectors

TECHNOLOGY	PROPOSAL NUMBER	PROPOSER	PRODUCT	ENERGY CONSUMPTION SECTOR: UTILITIES	INDUSTRIAL	COMMERCIAL	RESIDENTIAL	TRANSPORTATION
COAL PREPARATION AND WASTE RECOVERY	07	AMERICAN MINERALS INC.	CLEAN COAL	*	*			
	14	NORTH MARION DEVELOPMENT INC.	CLEAN COAL	*	*			
	18	STIRLING ENGINES INC.	CLEAN COAL	*	*			
	24	WESTERN ENERGY CO.	CLEAN COAL	*	*			
	29	UNITED COAL CO.	CLEAN COAL	*	*			
	32	COMMUNITY CENTRAL ENERGY INC.	CLEAN COAL STEAM		*	*		
	33	ATLANTIC RESEARCH CORP.	CLEAN COAL	*	*			
	36	COAL TECHNOLOGY CORP.	CLEAN COAL	*	*			
	42	MCDONNELL DOUGLAS ENERGY SYS. INC.	CLEAN COAL	*	*			
	52	CHEMION CORP.	CLEAN COAL	*	*			
ADVANCED COMBUSTION	21	COMBUSTION ENGINEERING	CLEAN COAL	*	*			
	23	UNIVERSITY OF FLORIDA	STEAM	*	*	*		
	26	TRW INC.	STEAM ELECTRICITY	*	*			
	38	COAL TECH CORP.	STEAM ELECTRICITY	*	*			
ATMOSPHERIC FLUIDIZED-BED COMBUSTION	08	CITY OF TALLAHASSEE	ELECTRICITY	*				
	10	UNIVERSITY OF CINCINNATI	STEAM	*	*	*		
	12	ENERGOTECHNOLOGY CORP.	ELECTRICITY CLEAN COAL	*				
	13	COLORADO-UTE ELECTRIC ASSOCIATION	ELECTRICITY	*				
	27	COMMUNITY CENTRAL ENERGY CORP.	STEAM		*	*		
	35	UNIVERSITY OF MISSOURI	STEAM		*	*		
	39	SOUTHWESTERN PUBLIC SERVICE CORP.	ELECTRICITY	*				

EXHIBIT 2.e, cont.

Application of Projects to Energy-Consuming Sectors

TECHNOLOGY	PROPOSAL NUMBER	PROPOSER	PRODUCT	UTILI-TIES	INDUS-TRIAL	COMMER-CIAL	RESIDEN-TIAL	TRANSPOR-TATION
				-------ENERGY CONSUMPTION SECTOR--------				
PRESSURIZED FLUIDIZED-BED COMBUSTION	04	AMERICAN ELEC. POWER SERV. CORP.	ELECTRICITY	*				
	11	WISCONSIN ELECTRIC POWER CO.	ELECTRICITY	*	*			
FLUE GAS CLEANUP	03	BABCOCK AND WILCOX INC.	ENVIRONMENTAL CONTROL TECH	*				
	17	NOXSO CORP.	ENVIRONMENTAL CONTROL TECH	*	*			
	34	ENERGY & ENVIRONMENTAL RESEARCH	ENVIRONMENTAL CONTROL TECH	*				
	40	RECOVERY SYSTEMS LIMITED	ENVIRONMENTAL CONTROL TECH	*				
	45	TENNESSEE VALLEY AUTHORITY	ENVIRONMENTAL CONTROL TECH	*				
	49	FMC CORPORATION	ENVIRONMENTAL CONTROL TECH	*				
	53	CHARWILL CORPORATION	ENVIRONMENTAL CONTROL TECH	*				

EXHIBIT 2.e, cont.

Application of Projects to Energy-Consuming Sectors

TECHNOLOGY	PROPOSAL NUMBER	PROPOSER	PRODUCT	-------ENERGY CONSUMPTION SECTOR-------- UTILI- TIES	INDUS- TRIAL	COMMER- CIAL	RESIDEN- TIAL	TRANSPOR- TATION
GASIFICATION	01	ELGIN-BUTLER BRICK CO.	FUEL GAS DIS- TILLATE FUEL		*			
	05	PENNSYLVANIA COAL TECH. INC.	COKE FUEL GAS ELECTRICITY	*	*			
	06	CONSOL/FOSTER WHEELER	FUEL GAS, STEAM ELECTRICITY	*	*			
	09	CALDERON ENERGY CO.	FUEL GAS, STEAM ELECTRICITY	*				
	19	M. W. KELLOG CO.	FUEL GAS, ELECTRICITY	*				
	30	DRAVO WELLMAN CO.	FUEL GAS, ELECTRICITY	*				
	31	SANITECH INC.	LOW - BTU FUEL GAS	*	*	*		
	46	QUESTAR SYNFUELS CORP.	ELECTRICITY		*			
	48	GENERAL ELECTRIC CO.	ELECTRICITY, STEAM	*	*			
GASIFICATION/ FUEL CELLS	37	ZTEC CORPORATION	ELECTRICITY	*	*	*		
	41	PPG INDUSTRIES	ELECTRICITY	*	*			
	43	WESTINGHOUSE ELECTRIC CORP.	ELECTRICITY	*				
IN-SITU GASIFICATION	20	ENERGY INTERNATIONAL	SNG, DISTILLATE LIQUID FUELS	*	*	*	*	*

EXHIBIT 2.e, cont.

Application of Projects to Energy-Consuming Sectors

TECHNOLOGY	PROPOSAL NUMBER	PROPOSER	PRODUCT	--ENERGY CONSUMPTION SECTOR-- UTILITIES	INDUSTRIAL	COMMERCIAL	RESIDENTIAL	TRANSPORTATION
LIQUEFACTION	25	OHIO ONTARIO CLEAN FUELS INC.	DISTILLATE LIQUIDS	*	*	*	*	*
	44	CHEMCOAL ASSOCIATES	SRC-I TYPE LIQUIDS	*	*	*	*	*
	47	TENNESSEE VALLEY AUTHORITY	METHANOL ELECTRICITY	*	*			*
INDUSTRIAL PROCESSES	02	STATE OF MINNESOTA	IRON, FUEL GAS		*			
	16	DOW CORNING CORPORATION	ENERGY RECOVERY BYPRODUCTS		*			
	22	WEIRTON STEEL CORPORATION	IRON, FUEL GAS		*			
	15	CLEVELAND ELEC ILLUMINATING CO.	ELECTRICITY	*				
OTHER	51	NATIONAL LIME ASSOCIATION	-					

EXHIBIT 2.f

UTILIZATION OF COAL RESOURCE BASE IN PROPOSED PROJECTS

CATEGORY	PROPOSAL NUMBER	TECHNOLOGY	COAL TYPE: ANTHRACITE	BITUMINOUS	SUB-BITUMINOUS	LIGNITE
COAL PREPARATION AND WASTE RECOVERY	07	Waste recovery		*		
	14	Waste recovery		*		
	18	Physical coal cleaning		*		
	24	Coal preparation			*	*
	29	Coal preparation		*		
	32	Coal preparation	*	*		
	33	Coal preparation		*		
	36	Waste recovery		*		
	42	Coal preparation		*		
	52	Chemical coal cleaning		*	*	*
ADVANCED COMBUSTION	21	Clean coal combustion		*	*	*
	23	Advanced combustion	*	*	*	*
	26	Advanced combustion		*		
	38	Advanced combustion		*	*	
ATMOSPHERIC FLUIDIZED-BED COMBUSTION	08	Circulating AFB		*		
	10	Circulating AFB		*		
	12	AFB & phys. cleaning		*		
	13	Circulating AFB		*	*	
	27	AFB	* (culm)			
	35	Multisolid AFB			*	
	39	Circulating AFB		*	*	

EXHIBIT 2.f, cont.

UTILIZATION OF COAL RESOURCE BASE IN PROPOSED PROJECTS

CATEGORY	PROPOSAL NUMBER	TECHNOLOGY	COAL TYPE: ANTHRACITE	BITUMINOUS	SUB-BITUMINOUS	LIGNITE
PRESSURIZED FLUIDIZED-BED COMBUSTION	04	PFB combined cycle		*		
	11	PFB turbocharged		*		
FLUE GAS CLEANUP	03	LIMB & Coolside		*		
	17	NOx/SOx	*	*	*	*
	34	Gas reburning		*		
	40	FGC/Phosphate by-product		*		
	45	Spray dryer		*		
	49	Removal of NOx/SOx		*		
	53	FGC/wet scrubbing		*		
SURFACE COAL GASIFICATION	01	Fixed/moving bed gasif.		*		*
	05	Clean fuel gas/coking		*		
	06	IGCC		*		
	09	IGCC		*		
	19	IGCC		*		
	30	Low Btu gasification		*		
	31	Fuel gas		*		
	46	IGCC		*	*	
	48	IGCC		*		
GASIFICATION/ FUEL CELLS	37	Solid oxide fuel cell	*	*	*	
	41	Phosphoric acid fuel cell				
	43	Gasification/fuel cell		*	*	

EXHIBIT 2.f, cont.

UTILIZATION OF COAL RESOURCE BASE IN PROPOSED PROJECTS

CATEGORY	PROPOSAL NUMBER	TECHNOLOGY	COAL TYPE: ANTHRACITE	BITUMINOUS	SUB-BITUMINOUS	LIGNITE
IN-SITU COAL GASIFICATION	20	In-situ gasification			*	
LIQUEFACTION	25	Coal/oil coproc.		*		
	44	Liquefaction		*		
	47	Methanol/IGCC		*		
INDUSTRIAL PROCESSES	02	Steel manufacturing		* (low volatile)		
	16	Silicon manufacturing	*			
	22	Steel manufacturing		* (low volatile)		
OTHER	15	Compressed air storage	- - - - - - - - - - -	NOT IDENTIFIED - -	- - - - -	- - - -
	51	Lime use	- - - - - - - - - - -	NOT IDENTIFIED - -	- - - - -	- - - -

EXHIBIT 2.g

UTILIZATION OF COAL RESOURCE BASE
IN FUTURE COMMERCIAL APPLICATIONS

CATEGORY	PROPOSAL NUMBER	TECHNOLOGY	COAL TYPE: ANTHRACITE	COAL TYPE: BITUMINOUS	COAL TYPE: SUB-BITUMINOUS	COAL TYPE: LIGNITE
COAL PREPARATION AND WASTE RECOVERY	07	Waste recovery		*		
	14	Waste recovery		*		
	18	Physical coal cleaning		*		
	24	Coal preparation			*	*
	29	Coal preparation		*(low sulfur)		
	32	Coal preparation		*		
	33	Coal preparation	*	*	*	*
	36	Waste recovery		*		
	42	Coal preparation		*		
	52	Chemical coal cleaning		*	*	*
ADVANCED COMBUSTION	21	Clean coal combustion	*	*	*	*
	23	Advanced combustion	*	*	*	*
	26	Advanced combustion		*	*	*
	38	Advanced combustion		*	*	*
ATMOSPHERIC FLUIDIZED-BED COMBUSTION	08	Circulating AFB	*	*	*	*
	10	Circulating AFB	*	*	*	*
	12	AFB & phys. cleaning	*	*	*	*
	13	Circulating AFB	*	*	*	*
	27	AFB	* (culm)	*	*	*
	35	Multisolid AFB	*	*	*	*
	39	Circulating AFB	*	*	*	*

EXHIBIT 2.g, cont.

UTILIZATION OF COAL RESOURCE BASE
IN FUTURE COMMERCIAL APPLICATIONS

CATEGORY	PROPOSAL NUMBER	TECHNOLOGY	COAL TYPE: ANTHRACITE	BITUMINOUS	SUB-BITUMINOUS	LIGNITE
PRESSURIZED FLUIDIZED-BED COMBUSTION	04	PFB combined cycle		*		
	11	PFB turbocharged		*	*	*
FLUE GAS CLEANUP	03	LIMB & Coolside		*	*	*
	17	NOx/SOx	*	*	*	*
	34	Gas reburning		*		
	40	FGC/Phosphate by-product		*		
	45	Spray dryer		*		
	49	Removal of NOx/SOx		*		
	53	FGC/wet scrubbing		*		
SURFACE COAL GASIFICATION	01	Fixed/moving bed gasif.		*		*
	05	Clean fuel gas/coking		*		
	06	IGCC	*	*	*	*
	09	IGCC	*	*	*	*
	19	IGCC	*	*	*	*
	30	Low Btu gasification	*	*	*	
	31	Fuel gas	*	*	*	*
	46	IGCC		*	*	
	48	IGCC		*	*	*
GASIFICATION/ FUEL CELLS	37	Solid oxide fuel cell	*	*	*	
	41	Phosphoric acid fuel cell	*	*	*	
	43	Gasification/fuel cell	*	*	*	

EXHIBIT 2.g, cont.

UTILIZATION OF COAL RESOURCE BASE
IN FUTURE COMMERCIAL APPLICATIONS

			COAL TYPE			
CATEGORY	PROPOSAL NUMBER	TECHNOLOGY	ANTHRACITE	BITUMINOUS	SUB-BITUMINOUS	LIGNITE
IN-SITU COAL GASIFICATION	20	In-situ gasif.			*	
LIQUEFACTION	25	Coal/oil coproc.		*	*	
	44	Liquefaction		*		*
	47	Methanol/IGCC		*	*	
INDUSTRIAL PROCESSES	02	Steel manufacturing	All coals if blended for low volatile matter			
	16	Silicon manufacturing	*			
	22	Steel manufacturing	All coals if blended for low volatile matter			
OTHER	15	Compressed air storage		*		
	51	Lime use	N/A	N/A	N/A	N/A

EXHIBIT 2.h

Summary of Selected Commercialization Data
as Presented in Submitted Proposals

TECHNOLOGY	DATE OF COMM'L	REGION OF APPLICATION	COAL TYPE	SCALE-UP FACTOR	POTENTIAL MARKET	PROJECTED PENETRATION OF POTENTIAL MARKET BY 1995
COAL PREPARATION AND WASTE RECOVERY	1990-1995	National	All ranks and conventional coal waste	1-1 to 1-100	100,000,000 to 200,000,000 tons per year	1-7%
ADVANCED COMBUSTION	1990-1995	National	All ranks	1-1 to 1-50	20,000 to 35,000 combustors	1-20%
ATMOSPHERIC FLUIDIZED-BED COMBUSTION	1989-1995	National	All ranks	1-1 to 1-2	11,000 to 45,000 MW	5-30%
PRESSURIZED FLUIDIZED-BED COMBUSTION	1991-1995	National	All ranks	1-1 or modular replication	60,000 to 112,000 MW	5-10%
FLUE GAS CLEANUP	1988-1993	9 midwest to 31 state region	All ranks	1-5 to 1-25	79,000 to 130,000 MW	20-50%

EXHIBIT 2.h, cont.

Summary of Selected Commercialization Data
as Presented in Submitted Proposals

TECHNOLOGY	DATE OF COMM'L	REGION OF APPLICATION	COAL TYPE	SCALE-UP FACTOR	POTENTIAL MARKET	PROJECTED PENETRATION OF POTENTIAL MARKET BY 1995
GASIFICATION	1990-1993	National	All ranks	1-1 to 1-20	0.2 to 5.0 Quads per year	1-60%
GASIFICATION/ FUEL CELLS	1991-1995	National	All ranks	1-1 to 1-10	3,000 to 34,000 MW	1-5%
IN-SITU GASIFICATION	1990-1995	Western U.S.	Sub-Bituminous Bituminous	1-1	In excess of 100,000,000 tons of coal per year	1-5%
LIQUEFACTION	1995	National	All ranks	1-2 to 1-100	230,000 BPD	1-5%
INDUSTRIAL PROCESSES	1991-1995	National	All ranks	1-3 to 1-90	30 to 60 million tons per year	1-5%
OTHER	N/A	N/A	N/A	N/A	N/A	N/A

CHAPTER 3: PRESENTATION OF SPECIAL ISSUES

ENVIRONMENTAL REQUIREMENTS

The solicitation process included an overall strategy for insuring that the Clean Coal Technology (CCT) Program would be in compliance with the National Environmental Policy Act (NEPA) and consistent with the Council on Environmental Quality (CEQ) NEPA regulations and the DOE guidelines for compliance with NEPA. This strategy included both programmatic and project specific environmental impact considerations during and subsequent to the selection process. The tight schedule imposed by the CCT legislation, however, required that some modifications be made to the normally applicable documentation and public review requirements. Moreover, the confidentiality requirements of the competitive PON process place certain restrictions on the NEPA review. Alternate procedures were implemented to ensure that environmental factors were fully evaluated and integrated into the decision making process to satisfy the Department's NEPA responsibilities. Offerors were requested to submit both programmatic and project specific environmental data and analyses as a discrete part of their proposals.

The environmental data submitted in each proposal were used by the Source Evaluation Board to prepare a report that focused on environmental issues pertinent to decision making. This report included a project specific analysis that summarized the strengths and weaknesses of each proposal against the environmental health safety and socio-economic evaluation criteria, including, to the maximum extent possible, a discussion of alternate sites and/or processes reasonably available to the offeror, a brief discussion of the environmental impact of each proposal, practical mitigating measures and, to the extent known, a list of permits which must be obtained in implementing the project. It also included a comparative programmatic environmental impact analysis. This report and other environmental information related to the demonstration projects proposed and the anticipated environmental impacts of the technologies in their commercial applications were provided to the Source Selection Official for consideration and use in the selection process. Upon award of a Federal financial assistance instrument, the offeror will be required to submit detailed site and project specific information. This information will be used as the basis for site specific NEPA documents.

Environmental characteristics of each of the generic categories of technologies proposed for demonstration (e.g. flue gas clean-up, atmospheric fluidized-bed combustion, liquefaction) are contained in Appendix A. While not derived from any specific proposal received in response to the PON, these environmental characteristics provide broad indication of the potential environmental effects and benefits of the differing technologies.

COSTS

The PON required that DOE not contribute more than 50 percent of the total costs of the project as estimated by DOE as of the date of award of financial assistance. The validity of the cost proposed by the applicants will be verified through pre-award audits and subsequent negotiations prior to award. DOE, therefore, is unable to disclose any cost information regarding the nine selected proposals at this time. Furthermore, DOE also is unable to disclose cost information on the other proposals received under the CCT PON at this time, since this may be confidential business information and in certain cases could have an impact on subsequent negotiations if, for any reason, a cooperative agreement is not actually awarded to any of the selected firms and an additional project or projects have to be selected.

APPENDIX A: TECHNOLOGY DESCRIPTIONS

This appendix contains the detailed characterizations for each of the nine emerging clean coal technologies for which proposals were received.

- **A.1** Coal preparation and waste recovery
- **A.2** Advanced combustion
- **A.3** Fluidized-bed combustion
  - Atmospheric
  - Pressurized
- **A.4** Flue gas cleanup
- **A.5** Gasification/IGCC
- **A.6** Gasification/Fuel cell
- **A.7** In-situ gasification
- **A.8** Liquefaction
  - Indirect
  - Direct
- **A.9** Industrial processes.

These technologies are similar only in that their successful commercialization will, in the long run, enhance the consumption of coal in the United States -- and do so in an environmentally-acceptable manner.

Each section starts with a detailed discussion of the subject technology, followed by its environmental characteristics. Each section concludes with a review of the status of the technology and development work in progress.

The information provided in this appendix is derived from DOE's Fossil Energy R&D Program.

A.1 COAL PREPARATION AND WASTE RECOVERY

A.1.1 Technology Description

Coal preparation and waste recovery processes utilize technologies that can substantially reduce the ash and sulfur contents of mined coals and high carbon residues, respectively. The final fuel form could be finely pulverized coal or perhaps a coal water mixture and the end-use targets are not only utility and large industrial boilers but also small industrial and commercial boilers, residential furnaces and even advanced energy conversion machines such as gas turbines and diesels.

Coal preparation processes may be divided into four categories: physical preparation, physical cleaning, chemical cleaning, and microbial desulfurization. Physical preparation refers to the crushing and sizing of coal and is used at essentially all mining operations to improve coal handling and transportation properties. Coal cleaning, also known as beneficiation, can be defined as the treatment of coal to separate extraneous matter and sulfur.

In physical beneficiation, the coal is crushed typically to a size of 2 inches or smaller. This liberates mineral matter, including pyritic sulfur. The crushed coal is then screen-sized into coarse-, intermediate-, and fine-size streams. As the size of the average coal particle decreases, greater liberation of the mineral matter is achieved. Offsetting this benefit, however, is the increased difficulty of separating finer particles of coal from finer particles of mineral matter, including pyritic sulfur. Each of the streams are processed with the coal-cleaning equipment appropriate for that size range.

Overall, the approach is dominated by separation processes based on differences in the specific gravities (densities) of the coal constituents. The coarse- and intermediate-sized streams are cleaned typically by specific gravity devices such as cyclones and baths of liquid media with densities just slightly greater than that of coal. The coal tends to float while the heavier ash and pyritic sulfur-bearing particles sink. The finest particles, although they have the greatest separation potential, are more difficult to separate. These are cleaned by a froth flotation process, a concept based on the differences in surface characteristics. A combination of these processes can remove up to 60 percent of the ash and pyritic sulfur, depending on the characteristics of the coal and the technologies applied. Product yields range between 60 and 90 percent; thermal recoveries range between 85 and 98 percent.

The development and use of chemical beneficiation processes recognizes that the sulfur in coal is present not only in an inorganic form known as pyritic sulfur but also as chemically-bound organic sulfur. Both forms of sulfur are transformed into a gaseous air pollutant, sulfur dioxide (SO_2), when the coal is burned. Physical cleaning technologies are capable of removing about 20 to 60 percent of the pyritic sulfur, but essentially none of the organic sulfur. On the other hand, chemical coal cleaning can remove most of the pyritic sulfur plus varying amounts of organic sulfur. Research on chemical coal cleaning methods is still in the early stages, but studies indicate that the costs will be significantly more than those for conventional physical cleaning processes.

The third advanced coal cleaning process, microbial desulfurization, is an innovative technology. Significant advances have been achieved recently in which it has been demonstrated that the reaction times can be reduced significantly and the ability to degrade organic sulfur into a removable form can be improved. This biologically-oriented organic sulfur removal technology is capable of removing the theophrenic sulfur portion of the organic sulfur and will generally be 20 percent more effective than physical methods for removing sulfur.

A.1.2 Environmental Characteristics

Utility and industrial interest in advanced coal cleaning technology has become particularly intense because of the concern over acid rain and the accompanying interest in developing alternative means to reduce sulfur dioxide emissions. The extensive application of advanced coal cleaning technologies offers the potential to be the most cost-effective means of significantly reducing sulfur dioxide emissions from existing electric utility, industrial, and perhaps smaller coal-burning facilities. The benefits extend further; e.g., cleaning reduces the ash content of the coal, which in turn reduces the cost of transportation (per unit of usable energy content), improves plant reliability, reduces on-site waste disposal costs, and, by increasing the heating value of the fuel, can improve the efficiency and reliability of plant operations. These advantages, coupled with the reduction -- perhaps elimination -- of post-combustion controls such as flue gas desulfurization (scrubbers), could more than offset the cost of the advanced beneficiation technologies.

A.1.3 Status of Development and Work In Progress

The Department of Energy's (DOE) Office of Fossil Energy (FE) is a major sponsor of both physical and chemical coal preparation research. Some of the work is performed in-house at DOE's Pittsburgh Energy Technology Center (PETC). The coal from advanced cleaning processes will burn more cleanly than most coals currently fired in industrial boilers or industrial processes. Boilers will usually be able to accept coals cleaned by advanced cleaning methods, and electricity so generated could be used by all applicable energy-consuming sectors, including commercial and institutional applications.

The advanced cleaning technologies will have wide application to both new and retrofit installations. In fact, with full commercialization of advanced coal cleaning technologies, it should become possible to clean the majority of eastern coals.

Advanced Physical Coal Cleaning

Research and development studies are in progress in each of four technical areas. A description of these processes and current R&D activities is given below.

Heavy-Liquid Cyclone

The use of "heavy liquids" such as Freon (DuPont's trade name for the fluorocarbon refrigerant) as a separating medium has been shown to yield close to the theoretical limit of separations of coal from ash and mineral constituents at very fine sizes (e.g., minus 400 mesh) in the laboratory. The heavy liquid serves as the fluid in which the particles are separated by gravity. Investigations are now in progress on some of the parameters that affect the performance of these cyclones. This technology has been tested in the one ton-per-hour size range, and conceivably could be introduced into the commercial marketplace within the next few years. During FY 1986, freon cyclone testing and an evaluation of feed particles-size effect will be completed and an evaluation of alternative heavy liquids initiated.

Froth Flotation

Froth flotation uses differences in surface characteristics to separate coal from its impurities. The froth flotation technique treats finely-ground coal with an oil-based substance that adheres to the coal. The mixture is fed into a "froth flotation cell" where air bubbles, generally created by a mechanical agitation device, attach themselves to the oil-coated coal and rise to the surface. The impurities remain in the tank.

Froth flotation is the only technology used routinely today to clean coal 28 mesh (595 microns) and finer. However, the separation efficiency attained is usually inferior to that of float/sink testing, and pyritic sulfur removal tends to be poor. New research efforts to evaluate advanced froth flotation concepts including microbubble flotation and microbially-assisted flotation have been introduced at the laboratory scale. During FY 1986, these research efforts will be concentrated on establishing performance levels for an advanced microbubble device and to establish the feasibility of microbially assisted flotation.

Selective Coalescence

Given the presence of an appropriate medium, aided by various additives, small coal particles will selectively coalesce, i.e., agglomerate, into larger particles. These particles can be separated from the undesirable impurities that do not coalesce. DOE is researching both the basic physical mechanisms that are involved in this phenomenon and the novel, non-aqueous, media such as liquid carbon dioxide that have the potential of yielding exceptionally high energy recoveries (greater than 96 percent) with better than 90 percent ash and pyritic sulfur removal. Testing of a liquid CO_2 bench scale continuous unit has been completed and laboratory research to better understand the basic mechanisms of selective coalescence is being continued.

Electrostatic/Magnetic Separation

Electric and/or magnetic fields can be applied to fine coal as a means to separate coal from its impurities. Differences in electric charge and differences in magnetic susceptibility cause the mineral matter and the coal to separate when passed through these fields. Past research on magnetic separation has been only marginally successful because of the low-level magnetic susceptibility of the mineral matter. New research efforts have been initiated to investigate electrostatic and electrostatically-enhanced magnetic separation.

DOE and EPRI are jointly funding a project to develop and test advanced physical fine-coal cleaning devices at a proof-of-concept scale of nominally 1 ton of coal per hour. The basis for the selection of the technologies to be tested will be their ability to significantly advance the state-of-the-art of sulfur and ash removal with favorable economics. The devices selected will be tested at the Coal Cleaning Test Facility (CCTF) operated by EPRI at Homer City, Pennsylvania.

Chemical Coal Cleaning

As stated earlier, chemical coal cleaning is required to remove the organic form of sulfur from coal. A chemical process, based on alkali displacement, is being researched by DOE. This concept, known as the TRW "Gravimelt" process, has demonstrated its capability to remove over 90 percent of the total sulfur and 95 percent of the ash from selected coals. The coals are exposed to a mixture of molten sodium hydroxide and potassium hydroxide (the alkali) for durations on the order of 2 hours at temperatures in excess of 700°F. Subsequently, the coal is skimmed, drained, and rinsed with water followed by a weak acid solution.

This laboratory-scale concept must be further refined to provide the engineering data needed for scale-up and to assess the required technological adjuncts such as alkali regeneration. DOE is proceeding with research on the fused salt process, testing this technology in a 20 lb/hr modular unit. The inherent need for caustic regeneration is a critical problem and is being pursued separately.

Bench scale development work on a microwave coal cleaning system has been discontinued because of very poor sulfur removal rates obtained during microwave reaction tests.

However, a new project was initiated in the area of cleaning chemically preconditioned coals. Historically, coal cleaning technologies have been applied to run of mine coal or more specifically to coal that had only been physically modified (grinding, screening, etc.) prior to cleaning (ash and sulfur removal). Past research has attempted to determine if certain physical changes to the coal, such as specialized grinding or electrostatic charging, could be used to enhance the ability of subsequent cleaning technologies to remove ash and sulfur. The objective of the newly initiated project is to identify any chemical modifications to the coal which would result in enhanced "cleanability" of the resultant solid stream. The aim of this project is to identify those candidate processes that show promise and to develop the solid cleaning segment of the process.

Microbial Cleaning

A substantive study to fully determine, at least at the laboratory scale, the feasibility of using biotechnology, i.e., microorganisms, for organic sulfur removal from coal has been initiated. One important question being addressed is the potential for enhancing the reaction rate which controls the pace of organic desulfurization.

A.2 ADVANCED COMBUSTORS

A.2.1 Technology Description

A coal combustor can be defined as a device mounted on a boiler or heater in which coal and oxygen are combined and combusted to produce usable heat. Combustors in varying sizes and configurations have been used by the industrial and utility sectors for years. However, the full realization of their performance potential has been limited by environmental constraints imposed by the New Source Performance Standards. The high operating temperatures necessary for substantial improvements in thermal efficiency have invariably resulted in the production of unacceptable levels of NO_x, while their use with a high sulfur coals has produced unacceptable levels of SO_x.

An advanced combustor is a device that will control or remove objectionable sulfur and particulate matter from coal-derived fuel before it is injected into retrofitted oil or gas boilers or heaters. Although these combustors are primarily intended for retrofit applications, they will also be applicable and appropriate for incorporation into the design of new facilities that utilize their compact size and flexibility of coal use. Typical of these projects is the Advanced Slagging Combustor effort which seeks to control particulate emissions by converting ash into molten slag which is removed before injection into the boiler or heater; NO_x formation by staged combustion to suppress temperatures; and SO_x formation by the injection of alkali compounds during combustion. These slagging combustors in advanced stages of development are suitable for incorporation either in new designs or in large retrofit applications in the heavy industrial and utility market (50 million Btu per hour or greater) in both direct and indirect boilers and process heaters. Research is in progress to develop advanced combustors for light industrial, commercial and residential sectors as well.

A.2.2 Environmental Characteristics

Advanced combustion technologies reduce emissions in the combustion process through advanced combustor design, boiler modification, or the introduction of sorbents into the combustor. Additional removal can be achieved by using coal preparation first to reduce sulfur and ash in the fuel to be fired.

The primary advanced combustion technology under development involves slagging cyclone combustors that offer the potential to reduce SO_2 emissions 70 to 90 percent when burning coal in a pulverized coal boiler. This reduction is achieved by introducing limestone sorbent into the combustor or into the combustion gases exiting from the combustor. If the sorbent is injected into the combustor, most of the limestone (and captured sulfur) exits with the molten slag, which is a solid waste.

If the sorbent is injected into the hot combustion gases, or if significant amounts of sorbent are carried into the boiler, it is captured in the particulate clean-up system for the boiler. In general, a baghouse or electrostatic precipitator (ESP) is used to achieve current utility or proposed industrial New Source Performance Standards (NSPS). Removal of ash as slag rejections is 80 to 90 percent. NO_x reduction is achieved in the slagging cyclone combustor by fuel staging (i.e., the combustor is operated sub-stiochiometrically, with combustion being completed in the boiler, where additional air is introduced). Overall, NO_x reduction of 50 to 70 percent relative to wall-fired, pulverized-coal (PC) combustors is achieved. Slagging combustors also have the potential to replace existing cyclone boilers, which are very high NO_x emitters. Technological alternatives for achieving NO_x reductions on existing cyclone boilers is limited, however, because they cannot be fitted with NO_x burners.

Other technologies can be used in advanced combustion systems to achieve environmental goals. Deep physical coal cleaning prior to combustion can generally achieve 40 to 60 percent sulfur reduction (depending on the ratio of pyritic to organic sulfur in the coal). Reburning in the boiler in conjunction with the staged cyclone combustor can achieve additional NO_x reduction.

Combustion in advanced combustors of deeply cleaned coal (physical beneficiation) can reduce emissions from retrofits by 40 to 60 percent without the need for capital-intensive modifications to the boiler. Particulate emissions can be reduced since the ash load into the ESP or baghouse is reduced; however, ash composition (and gas composition) can be affected, which might decrease ESP efficiency.

The use of coal mixtures could further enhance the attractiveness of these devices by providing an acceptable method for storing, handling and feeding coal in their operation and should be of particular interest to users in congested areas where environmental requirements are stringent or where space is not available for the conventional storage and handling of coal. Since the production of coal-water mixtures involves fine grinding, thereby lending itself readily to deep beneficiation, the use of coal-water mixtures in advanced combustors could further improve the efficiency of emission controls.

A.2.3 Status of Development and Work in Progress

Current methods of burning coal to produce usable thermal energy include:

- Circular and Cell Burners -- used on conventional pulverized coal boilers of up to 165 MM Btu/hr input.

- Spreader Stokers -- which project coal into the furnace over a fire bed with a uniform spreading action, permitting the fine particles to burn in suspension as the larger particles fall to the grate for combustion in a fast burning bed.

- Underfed Stokers -- in which coal is fed from a hopper by a reciprocating ram to a central section called a retort. Conveying mechanisms move the coal upward in a spreading motion over the air inlets (called tuyeres) where it is burned with the ash passing on to a dumping grate.

- Water-Cooled and Vibrating Stokers -- which consist of a tuyere grate surface mounted on, and in-contact with a grid of water tubes inter-connected with the boiler circulating system for positive cooling. Coal is fed to the grate where it is burned as it passes along the grate to the rear of the stoker, where ash is dumped into an ash pit.

- Traveling Grate Stokers -- in which the entire grate moves, acting as an endless belt on which the coal burns as it is conveyed to the rear of the furnace where the remaining ash is dumped.

- Cyclone Combustors -- which use crushed rather than pulverized coal and which complete the combustion process outside the boiler. Air is injected into the combustor, tangentially imparting a swirling motion to the incoming coal. Ash is fused in the combustion process and removed from the combustor as molten slag.

The ability of the cyclone combustor to use the abundant and relatively inexpensive surplus of high sulfur, high ash, low fusion temperature coals, along with recent developments that have shown that such combustors operated in a staged combustion manner can control the formation of NO_x during the combustion process. In addition, the formation of SO_x in these combutors effectively reduced by the injection of alkali compounds. These capabilities have resulted in a renewed interest in this technology by the Advanced Combustor Program.

The Advanced Combustor Program consists of three phases. In the first phase, near term slagging concepts appropriate to large industrial and utility applications are being developed through proof-of-concept stage. The second phase, which will be carried out in parallel with the first phase, will investigate a number of new longer-term combustor concepts potentially applicable to the entire range of users in the private sector. The feasibility of a number of innovative concepts that promise improvements beyond those attainable with the slagging concepts -- such as pulsed combustion, wet oxidation and vortex containment combustor -- will be investigated. The third phase will involve the selection, development and system integration of smaller size concepts usable in the light industrial, commercial and residential areas of the market.

The program includes such projects as are described below.

Phase I -- Near-Term Retrofit Concepts

- A slagging combustor has been developed that has been operated on three experimental units with capacities of 1, 10 and 50 million Btu per hour. The work has consisted of 2- to 3-hour experiments totaling approximately 800 hours of operation. The performance of the combustor has been characterized and preliminary economic studies have been conducted. In addition, as part of this commercialization plan the developer has installed a 50 million Btu per hour unit on an industrial boiler for long term testing.

- In a second effort, a compact slagging combustor mounted on the outside of a boiler designed for either oil or gas firing, is being developed that would remove coal ash before the combustion gases enter the boiler where heat exchange takes place. The design is intended to be more compact and more efficient in ash removal than devices now available.

Phase II -- Conceptual Evaluation

- The concepts being considered include: a wet oxidation process that would reduce the release of nitrogen and sulfur oxides and dry particulate material to the environment; a vortex containment combustor which would selectively remove ash particles in a combustor much smaller than conventional designs; a pulsed combustor that would burn coal-water mixtures in boilers designed for oil firing at higher than current efficiencies; and explosive communition of coal. In explosive communition, coal is mixed with water and raised to high pressure, which, when the pressure is dropped sharply, allows the water in the coal to expand, shattering the coal particulates and improving combustion.

Phase III -- Light Industrial, Commercial and Residential Concepts

- This phase has been initiated with a solicitation seeking proposals to develop advanced combustion technologies for use in these sectors. The PRDA requested proposals for the further development of existing bench scale combustors to the proof-of-concept stage and for the development and implementation of new and unique ideas that could lead to breakthroughs in this technology.

A.3 FLUIDIZED-BED COMBUSTION

A.3.1 Technology Description

In fluidized-bed combustion (FBC) technology, coal and sorbent (limestone) are introduced into the combustion chamber (furnace) in a bed of solids that is suspended through the action of fluidizing combustion air distributed from below. Fluidization promotes the turbulent mixing conditions required for high combustion efficiency and the capture of sulfur dioxide (SO_2) by the limestone particles. The resulting superior mixing characteristics permit the generation of heat at a substantially lower and more evenly distributed temperature. The lower temperature prevents the substantive formation of nitrogen oxides (NO_x) typical of standard coal combustion equipment.

Fluidized-bed combustion technology comprises two broad categories of processes: (1) atmospheric fluidized-bed combustion (AFBC), which operates at or near atmospheric pressure on the fireside; and (2) pressurized fluidized-bed combustion (PFBC), which is pressurized to a fireside pressure of 90 to 200 psig.

Atmospheric Fluidized Bed Combustion

In a fluidized bed, solid, liquid, and/or gaseous fuel together with inert material (e.g., sand silica, alumna, ash from the fuel) are kept suspended in the lower section of a combustion chamber through the action of fluidizing air distributed below the bed. Fluidization promotes the turbulent mixing conditions required for good combustion. The resulting improvement in mixing permits the generation of heat at lower and more uniform temperatures -- typically 1,500 to 1,600 ^{o}F.

The combustion process also controls emissions. The operating temperature is well below the thermal-NO_x formation point. Moreover, if a suitable sorbent -- such as limestone or dolomite -- is included as part as the bed material, the SO_2 released during combustion can be adsorbed, eliminating the need for downstream scrubbers. Particulate matter (PM) emissions are controlled downstream with a conventional electrostatic precipitator (ESP) or fabric filter. The AFBC process is typically applied to large industrial boilers (200,000 pounds per hour of steam or greater) and utility boilers for the production of steam for process needs, heating needs, and/or electricity generation. However, research is now being conducted to develop the technology for the light industrial, commercial and residential sectors.

Pressurized Fluidized Bed Combustion

PFBC involves burning coal in a bed of limestone (calcium carbonate) or dolomite (calcium magnesium carbonate) inside a furnace operated at elevated pressure. The bed material (sorbent) is fluidized through the injection of air at the bottom of the bed. SO_2 released during the combustion of coal reacts with the sorbent and forms a sulfate that can be discharged from the system as a solid waste.

The PFBC technology can be integrated into a steam-cooled, combined-cycle facility. The PFB combustor fires run-of-mine (ROM) coal, and energy is recovered through steam extraction, which generates electric power via steam turbines. The PFB combustion gases are exhausted to a gas turbine for the generation of additional electric power. The SO_2 and NO_x emissions are controlled in situ through sorbent injection and low-temperature combustion operating conditions, respectively. The PM emissions are controlled downstream with a conventional ESP or fabric filter.

A.3.2 Environmental Characteristics

Fluidized-bed combustion technologies burn coal to produce steam and electricity for utility and industrial use while reducing SO_2 or NO_x emissions in the combustor itself. The fluidization can be achieved through either the bubbling-bed or circulating-bed concept. The bubbling-bed concept attempts to prevent solids carryover by maintaining the fuel and inert material in the center of the combustor. The circulating-bed concept encourages solids carryover through the use of high-velocity air to entrain and return the solids to the combustor for additional combustion.

Fluidized-bed combustion for both the atmospheric (AFBC) and pressurized (PFBC) processes provides in-situ NO_x and SO_2 emission control. The operating temperature of the combustion process is well below the thermal NO_x formation point. The injection of an alkali sorbent -- calcite or dolomite -- into the bed of the combustor results in the capture of SO_2 released during the combustion process. The only downstream pollution control equipment needed is for particulate matter; either a conventional ESP or fabric filter can be used.

Emission data based on numerous operating hours show that FBC technology readily meets the NO_x, SO_x, and particulate emission requirements of the existing NSPS.

The secondary environmental impacts associated with FBC are on the order of those associated with conventional coal combustion. The FBC processes generate a dry solid waste material containing coal ash and calcium salt reaction products. This material is removed from the process as spent bed material and collected particulate matter, and is disposed of through conventional means.

A.3.3 Status of Development and Work in Progress

Atmospheric Fluidized-Bed Combustion

Nineteen suppliers of AFBC technology are currently active in the U.S. market. These suppliers account for over 100 units in commercial service to date. Of these, approximately 30 are designed to combust coal. These units, which are considered first-generation design vintage, range in steam-generating capability from 2,000 to 600,000 lb/hour at conditions comparable to conventional steam generators. Although first-generation AFBC is considered commercial for large-scale industrial boiler applications (200,000 lb/hour steam), a number of technical limitations remain. Many of these technical limitations (e.g., erosion of in-bed and waterwall tubes) have contributed to poor performance and reliability histories.

In response to these limitations, design concepts targeted for various applications, particularly utility power-generating plants, are being developed. Efforts to develop design concepts that will be accepted commercially by the utility industry have proceeded progressively from a 2-MW process development unit (TVA, EPRI), to a 20-MW pilot plant (TVA, EPRI), to three planned large-scale utility demonstration plants. Two such design concepts -- bubbling-bed and circulating fluidized-bed systems -- are proceeding toward commercialization through large-scale commercial applications. The three utility demonstration plants are:

- Colorado-Ute, Nucla Station, 110 MW -- A new, circulating-bed boiler will be built to repower 36 MW of existing steam turbine/generator capacity and power a new 74-MW steam turbine/generator. The boiler is scheduled for service in 1986. Participants in this project include Colorado-Ute, Pyropower, Stearns Catalytic, Peabody Coal, Westinghouse, EPRI, and the National Rural Electric Cooperative Association.

- Northern States Power, Black Dog Station, 125 MW -- This retrofit of an existing 100-MW PC boiler upgraded to 125 MW with a bubbling-bed design is scheduled for service in 1986. Participants include Northern States Power, Foster-Wheeler, Stone and Webster, and EPRI.

- Tennessee Valley Authority, Shawnee Station, 160 MW -- A new AFBC boiler to repower and extend the life of an existing 160-MW steam turbine-generator through installation of a bubbling-bed design is scheduled for service in 1989. Participants include TVA, Duke Power, Combustion Engineering, State of Kentucky, DOE, and EPRI.

In addition to the large-scale work being performed by various groups, DOE is currently pursuing advanced concepts of second-generation AFB technology that will significantly improve economics and performance for intermediate applications (between 75,000 to 150,000 lb/hour steam). In addition, special AFB applications of less than 50,000 lb/hour steam are being pursued for the commercial/institutional and multifamily residential markets.

Pressurized Fluidized-Bed Combustion

The PFBC process is not yet as technically mature as AFBC. Significant R&D has been conducted on PFBC over the past 10 years, and work has progressed to the point where sufficient data are available to design and construct a first-entry PFBC coal-fired demonstration plant.

The origin of PFBC technology can be traced to the Winkler gas generator developed during the 1920s in Germany. The technology evolved using atmospheric combustor equipment. In the 1950s, pressurization of the fluidized-bed combustor, combined with gas turbine expansion of the flue gas, was proposed as a means of achieving improved power generation efficiency.

Interest in the PFBC in conjunction with a combined-cycle increased significantly in the early 1970s, when major research efforts were sponsored by U.S. government agencies. EPA initially sponsored research at the Exxon "Miniplant," Argonne National Laboratory, and at the Combustion Power Company. DOE took over the PFBC program, which progressed to pilot-scale developmental work at the IEA Grimethorpe facility and at test rigs at General Electric (Long Term Materials Test Facility), New York University, and Curtis-Wright (Small Gas Turbine facility). Additionally, DOE has developed several hot-gas cleanup devices which are being tested at the New York University facility.

Although the fundamental effects of pressure on fluidization and combustion are not fully understood, certain enhanced PFBC characteristics have become apparent based on test facility experience. Several approaches to the development of PFBC have resulted. The two approaches being considered by the utility industry for first-entry demonstration are the steam-cooled, combined-cycle system and the turbocharged boiler system.

Currently, DOE research activities are supporting industry in the demonstration and commercialization of first-entry PFBC systems by the early 1990s. This support includes a follow-on effort at Grimethorpe to develop pilot-scale data on combustion efficiency using a coal slurry feed system, testing of advanced hot gas cleanup devices, and the collection of performance data from an updated, U.S.-designed, in-bed heat exchanger. Other DOE-sponsored activities include metal wastage studies to improve understanding of erosion/corrosion phenomena, and operation of the New York University test facility to test process components and evaluate operating parameters.

In support of the DOE-sponsored PFBC developmental efforts, EPRI has emphasized R&D on materials and hot gas cleanup. EPRI has also funded tests at two PFBC gas turbine simulators to provide the data needed to select turbine blade materials. Tests sponsored by DOE have shown that an ESP could be expected to perform efficiently at the gas conditions of the turbocharged boiler. Brown Boveri and Research-Cottrell are also evaluating the practical aspects of the ESP for turbocharged boiler application.

A.4 FLUE GAS CLEANUP

A.4.1 Technology Description

Currently available options for sulfur dioxide (SO_2) control consist primarily of physical coal cleaning, fuel switching, and flue gas cleanup. Each has associated advantages and disadvantages. Conventional coal cleaning is already in wide practice where it is presently economic to do so. The capability to significantly reduce the sulfur content of coals by conventional coal preparation, however, is limited since only some of the inorganic sulfur contained in the mineral portion of the coal can be removed.

Switching to low sulfur coals, although likely to be the lowest cost option available, also has a number of potential disadvantages. Analyses show that the high sulfur coal industry would be severely affected. Fuel costs could be expected to increase both as a result of greater demand as well as higher transportation costs. Coal characteristics such as hardness, ash content, and heating value generally differ which could result in problems such as exceeding particulate control standards and causing plant derating unless substantial plant modifications were undertaken to accommodate the different characteristics of low sulfur coal.

The third major approach is to clean the flue gases. Flue gas cleanup technology involves the control of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM) emissions released during coal combustion. In the case of sulfur oxides, mainly sulfur dioxide with a few percent of sulfur trioxide, many processes have been proposed as ways to reduce their concentrations in combustion gases. As a general rule, these processes can remove from 80 to 90 percent of the sulfur oxides from a combustion gas containing 0.2 to 0.3 percent of these oxides. Stack gas treatment processes may be divided into two broad categories: wet and dry, depending upon whether the sulfur oxide absorber is in a liquid or dry solid form. The wet processes are further divided into non-regenerative and regenerative types. All dry processes are regenerative in nature.

In wet processes the sulfur oxides are removed from the stack gases by scrubbing with an aqueous solution or slurry. To avoid vaporization of the water and associated problems, the gas must be cooled before it enters the scrubber. Several different types of scrubbers have been designed for achieving intimate contact between the gas and the scrubbing (absorbing) liquid. Although liquid-gas scrubbing is simple in principal, several problems arise in practice. These problems include deposition of scale especially with a slurry absorber, blockage or plugging of the demister, and corrosion and erosion of the equipment.

The equipment for dry desulfurization scrubbing of stack gases is generally simpler than the equipment used for wet scrubbing. However, reaction of sulfur oxides with a dry sorbent is much slower than with a solution or even a slurry. To overcome this drawback, dry scrubbers must be large in order to expose a large surface area of solid absorber to the stack gases.

Currently, the technology comprises two generic process categories. These are (1) dry sorbent injection and (2) post-combustion gas cleanup. The first category, dry sorbent injection, involves the injection of dry SO_2 sorbent such as limestone directly into the combustion zone to capture SO_2 in-situ. The second category, post-combustion gas cleanup, involves the injection of sorbents in a slurry, aqueous liquor, or dry powder form into the combustion gas stream downstream of the boiler (e.g., into the exhaust gas duct) to capture SO_2 following combustion.

In the area of NO_x control, work to date has focused on combustion modification (air staging) and flue gas treatment. Both approaches have now been commercialized. Air staging is characterized by low cost but has limited potential (on the order of 50-60 percent NO_x removal maximum). Flue gas treatment, on the other hands, offers high effectiveness but with costs that are presently considered prohibitive in the United States. Recently, increased emphasis has been placed on another combustion modification approach termed variously as reburning, fuel staging or in-furnace NO_x reduction. The process involves the injection of fuel into the combustion off-gases, followed, after a suitable residence time, by the addition of sufficient air at a somewhat lower temperature (roughly 1,000°C) to complete the combustion process. Modifying the combustion process in this manner destroys NO_x contained in the original combustion stream.

The reburning process is very complex. NO_x reduction potential appears to be a function of a relatively large number of process parameters, including temperature, relative fuel split between the primary combustion zone and the reburning zone, primary and reburning zone air-to-fuel ratios, gas residence time in the reburning zone, as well as the nitrogen content of the reburning fuel. If not correctly implemented, NO_x can actually be generated in the reburning zone from the reburning of fuel-bound nitrogen. In addition, the potential exists for reducing combustion efficiency as the result of incomplete fuel combustion. It would appear that to realize the full potential of this technology, further research is required to better define the mechanisms involved, pinpoint the free radical species of primary interest, and enhance the generation of these free radical species.

Some work is also being supported on the development of cleanup processes with the capability of simultaneously controlling both SO_2 and NO_x at the 90 percent level. The most technologically mature processes under development include the electron beam/spray dryer, electron beam/ammonia, fluidized bed copper oxide, NOXSO, and a modified lime spray dryer approach.

A.4.2 Environmental Characteristics

Currently available post combustion cleanup technology for SO_2 control essentially consists of using either wet limestone scrubbers or lime spray dryers. Wet limestone based scrubber processes are most commonly used. There are a number of reasons for this: limestone is much less expensive than alternative reagents, such as lime; and the cost differential becomes magnified as the sulfur content of the coal increases. The increasing use of forced oxidation in conjunction with limestone scrubbing generates a gypsum product that is readily dewatered and negates many of the problems associated with the handling and disposal of a thixotropic sulfite sludge. The potential also exists for capital cost reductions through elimination of dewatering equipment. Utilities must, however, cope with the fly ash disposal problem and believe that the added burden of FGD waste disposal compounds the existing fly ash disposal problem. Limestone scrubbers are effective (in excess of 90 percent SO_2 control) but are relatively expensive to purchase and operate. Reliability and availability have been problem areas as well as waste handling and disposal.

The spray dryer can offer advantages over the commercially available limestone scrubbers especially for retrofit installations where space requirements and availability of land for waste disposal can limit the application of wet scrubbers or where remaining boiler life is low. Spray dryers generally have lower capital costs than scrubbers. The spray dryer cleanup systems capture sulfur dioxide by contacting the hot flue gas with a finely atomized line slurry in a spray dryer vessel. The water in the slurry is evaporated by the sensible heat in the flue gas and the SO_2 reacts with the lime to form a dry calcuim sulfite/sulfate product. The solid product plus ash is collected in the electrostatic precipitator or baghouse. The resulting dry solids product is more manageable than the sludges produced in many wet scrubbing processes. These solids can be disposed of in suitable land fills. If high concentration of unreacted alkalis remain, however, special consideration may be needed in its disposal. It should be noted also that application of the lime spray dryer processes to high sulfur coals is in a relatively early stage of development, although it can now be considered commercially proven for use with low-sulfur western coal. More compact and somewhat less complex than the wet limestone scrubbers, its economic advantages over limestone scrubbers decrease with increasing coal sulfur content as a result of higher reagent costs.

Regenerable scrubbing processes do not produce a throw-away solid waste, but instead produce saleable products such as elemental sulfur or sulfuric acid. In the dry sorbent approach, a solid sorbent is used to absorb SO_2 and NO_x. Upon regeneration at higher temperature using a reducing gas (produced from coal), sulfur and nitrogen compounds are cleaned. These compounds are subsequently destroyed or converted to saleable products using commercially available technologies. Consequently, regenerable systems avoid the growing problem of disposal of the solid wastes generated by traditional flue gas cleanup technologies.

A.4.3 Status of Development and Work in Progress

Dry Sorbent Injection

Limestone Injection Multi-stage Burners (LIMB) is an emerging technology that is currently undergoing research and development at the bench, pilot, prototype, and demonstration plant levels. The thrust of ongoing research is to identify those factors that govern performance to optimize removal efficiency. An important aspect of this goal is the normalization of all site-specific factors to develop widely applicable process designs.

EPA, EPRI, DOE, and private industry are funding research by domestic and international boiler suppliers to optimize low-NO_x combustion/alkali injection techniques. A number of major test programs have been completed or are being contemplated to prove these concepts:

- EPA is promoting major demonstrations. A commercial-scale demonstration of LIMB on a wall-fired boiler is now in progress. A competitive solicitation also is in progress that will lead to a prototype-scale demonstration on a tangentially fired boiler. Field testing for these demonstrations will occur in 1987 and 1988, respectively.

- EPRI is planning four prototype demonstrations (50 to 100 MW). If these are successful, EPRI plans to support a full-scale commercial demonstration of LIMB at the 400-MW level (or greater).

- DOE sponsored a recently completed test of sorbent injection on a low-sulfur western coal (lignite) PC boiler. Preliminary analysis of the data showed favorable results. Further work is contemplated.

- Conoco sponsored a recently completed test on an industrial PC boiler. The demonstration yielded favorable results with respect to performance objectives. Further testing was also performed on sorbent injection in the duct upstream of the ESP.

- Pennsylvania Electric is sponsoring (with some support from EPA) an internal LIMB research program. Parallel contracts are in place with two technology suppliers (B&W and Research-Cottrell) to develop a commercial design concept. One contract will be awarded for commercial testing.

- Internationally, a number of countries are currently conducting research. Two significant contributors are Canada and West Germany. Three jointly funded test programs have been completed or are under way in Canada. Two commercial LIMB facilities are in service in West Germany and additional facilities are scheduled for near-term commercial service.

Post-Combustion Gas Cleanup

Advances in post-combustion gas cleanup are being made with respect to both process improvements and advanced processes. These improvements and processes can be applied to new plants or retrofitted to existing facilities if space and economic constraints permit.

Process Improvements

Numerous activities are being conducted by both the private and public sectors to improve the operation of existing emission control systems. These include:

- For existing flue gas desulfurization (FGD) systems, research efforts focus on the use of organic acids or magnesium salts to enhance SO_2 removal efficiency and reagent utilization. Results indicate that a removal efficiency of 95 percent can be achieved at reduced operating costs.

- For existing and new FGD systems, research is being conducted on reducing fresh water consumption and cleaning up waste water discharges. The private sector, in conjunction with EPRI, is conducting research to reduce FGD water consumption, including recycling and biofouling control as well as integrated water systems for power plants.

- For SO_2 control, a promising low-cost FGD option is dry injection of a sorbent in the flue gas before the fabric filter. EPRI has demonstrated this process, which is applicable to both new and existing low-sulfur coal facilities, in a full-scale facility. Additional research is proceeding on high-sulfur coal applications for use with ESPs, for improved waste fixation and disposal, and for system optimization, as well as for use with lower cost alternative reagents. Based on the success of this process development, the Public Service Company of Colorado has announced the use of a dry injection system for a new 500-MW coal-fired unit.

- In the area of NO_x control, most of the work to date has focused on combustion modification (air staging) and flue gas treatment. Both approaches have now been commercialized. Reburning is currently being evaluated in the United States and Japan. Experimental results suggest that the combination of reburning with conventional air staging can result in NO_x reduction levels approaching those now attainable only through relatively expensive flue gas treatment processes.

- For PM control, research efforts are centered on performance improvement and optimization. In response to concerns related to trace element and inhalable particulate matter emissions, substantial emphasis is being placed on the removal of submicron-sized particles. Examples of these research efforts include electrostatic, electromagnetic, and sonic horn augmentation for fabric filtration; two-state ESP; and use of additives.

Advanced Processes

Significant long-term research is currently under way in the areas of combined SO_2/NO_x control, SO_2 control, NO_x control, and particulate control:

- Research and development activities in combined SO_2/NO_x flue gas cleanup are focusing on the development of processes capable of simultaneously controlling SO_2 and NO_x at the 90 percent level. Some of the most technologically mature processes under development include (1) the electron beam/spray dryer, (2) electron beam/ammonia injection, (3) fluidized bed copper oxide, (4) NOXSO, and (5) a modified lime spray dryer approach. The current development status of these technologies ranges from bench-scale to proof-of-concept. Additional process concepts currently in the early laboratory stage of development are the moving-bed copper oxide, and electrochemical processes.

- For advanced SO_2 control technologies, the primary emphasis is on reagent regeneration and saleable product processes to eliminate or minimize solid waste disposal problems. The Flakt Boliden (sodium citrate reagent) and CONOSOX (potassium salt reagent) processes are in pilot-scale development, with commercial availability projected for the late 1990s. Advanced limestone/gypsum FGD processes, which produce marketable gypsum through forced oxidation of the spent slurry, are being developed for application in the United States. A 23-MW prototype of the Chiyoda Thoroughbred 121 process was successfully tested.

- For post-combustion NO_x control, the selective catalytic and selective noncatalytic reduction systems are the most advanced. Pilot-scale systems of these two technologies have been tested on coal-fired power plants and found to be effective. However, these processes are more expensive than combustion modification, and major improvements are needed in the process control subsystem, extension of catalyst life, cost reduction, and elimination of ammonia leakage.

- In the area of particulate matter control, DOE has two projects under way. The first is evaluating the use of an electron beam to precharge particles to improve collection efficiency in an electrostatic precipitator. The second is investigating the application of acoustics to agglomerate particles so that they may be more easily collected in a relatively simple mechanical collector such as a cyclone.

Small Scale Applications

To date, the FGCP has been devoted almost exclusively to electric utility applications since they are the largest users of coal. In recognition of the fact that the utility sector is firmly committed to the continuing use of coal and in consonance with the need to expand the use of coal in the light industrial, commercial, and residential sectors, a planning initiative on small scale applications has been instituted.

A.5 GASIFICATION/IGCC

A.5.1 Technology Description

Surface coal gasification technology includes a series of processes that convert coal into a fuel and/or a chemical feedstock. This conversion is accomplished by introducing a gasification agent (air or oxygen and steam) into a reactor vessel that contains a suitably prepared coal feedstock operating under controlled conditions of temperature, pressure, and flow regime (moving, fluidized, or entrained-bed). The proportion of the various gaseous components exiting the reactor (e.g., carbon monoxide, carbon dioxide, methane, hydrogen, water, nitrogen, hydrogen sulfide) is influenced by the type of coal, composition of the gasification agent, and the thermodynamics and chemistry of the gasification reactions as controlled by the operating parameters imposed.

Once generated, the crude gas leaving the reactor is processed through a number of sequential gas treatment steps determined by environmental requirements and the end products sought. These gas treatment steps generally can be thought of in terms of one of two types of systems. Low temperature (i.e., 100 to 300°F or cold) systems most often are accepted as representing state-of-the-art technology. One the other hand, high temperature (i.e., 800-1,200°F, hot) gas cleanup technology is still in the research and development stage and represents the opportunity to make significant improvements (e.g., economic, efficiency) in future application of gasification technology. This series of sequential steps that constitute a coal gasification process can be used to convert all types of coal into a wide range of products, including clean low- and medium-Btu gas suitable for industrial processes and power generation; a high-Btu gas (pipeline quality) that can be used as a substitute natural gas; and/or a synthesis gas suitable for subsequent conversion into liquids that range from chemical feedstocks to high-grade transportation fuels.

Gasification of coal with air creates a low-Btu gas with heating values in the range of 125 to 150 Btu per standard cubic foot. Gasification of coal with oxygen creates a medium-Btu gas with heating values in the range of 300 to 350 Btu per standard cubic foot. Both can be used directly as fuel. Medium-Btu gas can be processed and upgraded to a substitute natural gas with heating values ranging from 950 to 1,000 Btu per standard cubic foot or used as a feedstock for chemical synthesis operations yielding products such as methanol and ammonia.

Despite the variety in specific gasification processes, all are fundamentally similar in that they involve conversion (carbonization and gasification) of coal to produce synthesis gas. Run-of-mine (ROM) coal with included mineral matter is converted to a clean gas containing CO and H_2 for use as fuel or for further processing in an environmentally acceptable manner. Surface coal gasification technology can be used in four energy systems of potential importance; specifically, in the production of:

- Fuel for use in integrated combined-cycle electric power generation units;
- Fuel gas (low- or medium-Btu) for industrial processes;
- Synthesis gas for use as a chemical feedstock, the production of hydrogen, conversion to substitute natural gas and as a feedstock for indirect coal liquefaction processes; and
- Coproducts as char, fuel gas, and distillate products for use as fuels in advanced energy conversion machines.

A.5.2 Environmental Characteristics

Surface gasification technologies convert coal (in the presence of an oxidant -- air or oxygen -- and steam) to a fuel gas composed primarily of carbon monoxide and hydrogen. The fuel gas is burned in boilers to raise steam or in gas turbine combustors to generate electricity directly. If desired, the carbon monoxide/hydrogen mixture can be processed further to make methanol. In the production of the fuel gas from coal, the ash materials are discharged as dry solids and the fuel-bound nitrogen and sulfur are converted to ammonia (NH_3) and hydrogen sulfide (and other organic sulfides such as COS and mercaptans). The benefit of the gasification technologies is that the gaseous sulfur and nitrogen compounds can be removed before combustion using either wet scrubbing or high-temperature absorption/adsorption processes.

Hydrogen sulfide removal can be achieved through chemical absorption or physical adsorption after gas cooling or by adsorption on metal oxides at high temperature (1,000 to 1,200°F). These processes can remove more than 99 percent of the gaseous sulfur compounds before combustion of the gases. The sulfur species absorbed in chemical solutions (cold cleanup) can be recovered as elemental sulfur or converted to sulfuric acid. From the metal oxide adsorption process (hot cleanup), the sulfur compounds can be recovered as sulfur or converted to sulfuric acid or solid sulfates (such as calcium sulfate), which can ultimately be disposed of by landfilling.

In addition, sulfur compounds can be captured within the gasifier itself through the addition of limestone or dolomite. Capture levels of approximately 90 percent are possible using this method and further capture ("polishing") can be achieved by treating the fuel gas with a metal oxide adsorption process to exceed 99 percent total sulfur removal.

Nitrogen compounds (principally ammonia) are generated in the gasification process and, depending on the gasifier operating temperature, are contained in varying amounts in the fuel gas. The highest ammonia levels are produced in the lowest temperature reactor -- fixed-bed gasifiers; lesser amounts are produced in fluid-bed reactors; and the lowest amount in entrained reactors (which have the highest operating temperature). The nitrogen compounds are easily removed in cold cleanup systems by dissolution in waste liquor streams and are subsequently recovered as saleable ammonia for fertilizer applications. After cold cleanup, fuel gas contains a small enough level of ammonia that, upon combustion, the NO_x emission is far below NSPS emission limits. With hot gas cleanup systems, the ammonia passes through into the final fuel; thus, NO_x emissions must be controlled by combustion modifications or external de-NO_x processes. In either treatment, the fuel gas can meet current NSPS limits.

When the fuel gas is burned in a gas turbine to produce electricity, the removal of entrained particulate matter is controlled to a low level to protect the gas turbine. In this case, the exit gases from the combustor are well below NSPS particulate emission limits and the captured solids are disposed of as solid wastes along with the primary ash discharged from the gasifier. When the fuel gas is burned directly in a boiler the suspended solids are controlled in the boiler discharge gas by conventional means. In this case, however, the level of input solids will be significantly below the level normally produced from the coal and will require less than total removal to achieve compliance.

The solid wastes from the gasifier will be coal ash, which can be disposed of in the same manner as coal-fired boiler ash. When limestone is injected into the gasifier, the solids will contain calcium sulfides. It will be necessary to oxidize these solids to convert sulfides to sulfates, which are inert and can be landfilled.

Some gasification processes can produce tars and oils during early stages of the gasification reactions. In these gasification processes using a cold-water scrubbed cleanup system, the wastewater will require treatment to remove organic compounds before discharge. However, in systems employing hot gas cleanup systems, the gases are maintained at high temperature (greater than 1,000°F) and burned directly at this temperature. The tars and oils produced are maintained in the vapor phase and serve as fuel; hence, no tars or oils are emitted.

A.5.3 Status of Development and Work in Progress

Gasification processes of all types are in operation in the United States and on a broad scale worldwide. Nonetheless, considerable research and development work is now in progress to produce advanced, environmentally acceptable gasification systems that are viable within the fuel economy of the United States.

Even though the decline of oil prices in the 1980s has prompted a reassessment of priorities for the commercialization of processes, numerous demonstration studies have been completed or are under way and a commercial plant for production of substitute natural gas has been put on stream. In several cases where a specific application of coal gasification technology could be used to accomplish corporate objectives, industry has assumed the responsibility for continuing the development of advanced gasifiers from the proof-of-concept stage into the demonstration phase. In others, the government has provided some form of support to stimulate further development. Some of these demonstration projects include:

1. Great Plains Gasification Project -- Great Plains is a commercial facility using Lurgi gasifiers to produce 125 million Btu per day of substitute natural gas for commercial pipeline distribution. DOE provided a loan guarantee to assist industry in this venture. After successfully starting up and operating the facility, the Great Plains Gasification Associates Partners notified the government on August 1, 1985 that they were terminating their participation in the North Dakota project and the partnership on that date defaulted on the $1.5 billion federal loan it received to build the plant. DOE has assumed ownership of the facility and continues to operate the plant while studying sale or lease options for future plant operations.

2. Coolwater Coal Gasification Project -- The Coolwater plant consumes 1,000 tons of coal per day in a Texaco gasifier to produce a synthesis gas and steam for an integrated coal gasification combined-cycle system that has been constructed and is being operated in Daggett, California.

3. British Gas Corporation/Lurgi Slagging Gasifier -- The British Gas Corporation has constructed a demonstration size gasifier with an 8-foot diameter shaft at its Westfield Test Facility. The gasifier is being operated to confirm scale-up parameters for a commercial version.

4. Tennessee Eastman, Chemicals from Coal -- A 900-tons-of-coal-per-day Texaco gasifier has been constructed at Kingsport, Tennessee, as part of a demonstration plant. This plant will

continue development of the gasifier and a process for the production of chemicals from coal.

5. KilnGas Coal Gasification Process -- A 600-tons-of-coal-per-day facility has been constructed to produce a low-Btu fuel gas for a modified 50-megawatt boiler as a joint venture of Allis-Chalmers, EPRI, and 12 electric utilities. This project uses the KilnGas gasifier developed by Allis-Chalmers.

6. TVA, Ammonia From Coal -- A Texaco gasifier (225 tons per day) is being used in a development project to produce ammonia for fertilizer manufacture.

7. High Pressure, High Temperature Winkler Gasifier -- Rheinbraun, Inc. of West Germany has constructed and is operating a demonstration size (55 tons of coal per hour) high-temperature, high-pressure Winkler gasifier as the first phase of a program to develop this gasifier and a process for producing methanol from coal.

In addition to these activities, DOE has supported the development of other advanced gasifier systems through the process development unit (PDU) research stage. Examples of these are the Catalytic Coal Gasification Gasifier, the Agglomerating, Pressurized, Fluidized Bed, (e.g. U-Gas and KRW) Gasifiers and the Carbon Dioxide and Hygas reactor systems.

These development activities have provided a variety of gasifiers and processes that offer a full range of operational as well as feedstock capabilities. Moreover, they have demonstrated the ability to convert coal into a variety of gaseous and liquid fuels as well as chemical feedstocks. Any subsequent implementation of gasification technology will depend on how successful the demonstration projects are in showing that the technology is (1) economic, (2) in tune with social/environmental requirements, and (3) responsive to a number of market transition factors.

A.6 GASIFICATION/FUEL CELLS

A.6.1 Technology Description

Fuel cells directly transform the chemical energy of a fuel (e.g., synthesis gas, reformed natural gas, reformed distillate fuel) and an oxidant (oxygen) into electrical energy without the inherent efficiency limits of heat engine cycles. A hydrogen-rich gas or hydrogen is fed to one electrode and oxygen or air is fed to the other. One of the reactants is dissociated at the electrode/electricity interface into electrons and ions to provide a direct current (DC) to the circuit connecting the two electrodes.

Energy conversion in fuel cells is potentially more efficient (40 to 60 percent, depending on fuel and type of fuel cell) than traditional energy conversion devices because electricity is generated directly in the fuel cell instead of going through an intermediate conversion step (i.e., burner, boiler, turbines, and generators). The fuel cell system efficiency can be increased further by using the byproduct heat of reaction to generate steam or to heat water.

Coal is a target fuel for phosphoric acid, molten carbonate, and solid oxide fuel cell power plants. A typical fuel cell system using coal as fuel would include a coal gasifier with a gas cleanup system, a fuel cell to generate electricity (DC), a power processing section to convert DC to alternating current (AC) electrical power, and a heat recovery system. The heat recovery system would be used to capture rejected thermal energy to produce additional electrical power in bottoming heat engines.

A.6.2 Environmental Characteristics

A fuel cell requires a very clean fuel to avoid contamination and degradation of its performance. Its tolerance to sulfur, particulate matter, and other contaminants is very low; hence, during operation, emissions of air contaminants, suspended solids, solid wastes, and contaminated wastewater are insignificant. The level of emissions from an integrated fuel cell/gasifier system will be similar to the level emitted from surface coal gasification systems, except that combustion of the gas does not occur and NO_x and SO_x emissions will be negligible.

A.6.3 Status of Development and Work in Progress

The development of fuel cells in the United States has been under way for the past 25 years for high-technology applications such as the space program.

During the 1970s, utilities began to investigate fuel cells as an efficient, nonpolluting, alternative power generation technology to meet their load growth.

Three types of fossil fuel cells using different electrolytes are now being developed: (1) phosphoric acid, (2) molten carbonate, and (3) solid oxide. Phosphoric acid systems are the most mature of the fuel cell systems under development by DOE and have the greatest private-sector cost-sharing. Electric and gas utilities have shown strong and continuing interest in phosphoric acid systems.

Within DOE's phosphoric acid program, two fuel cell applications are being pursued: electric utility systems and on-site integrated energy systems. The primary difference between the two applications is fuel cell size, with the electric utility systems being in the multi-MW range and the on-site systems in the 40 to 400 kW range. Commercial prototype phosphoric acid fuel cell (PAFC) power plants are expected to be delivered by the end of the 1980s.

PAFCs have to date been fueled by natural gas or naphtha, which is reformed to produce a hydrogen-rich fuel prior to being fed to the cell. Ongoing activities in PAFC development include:

- Under the utility program, United Technologies Corporation (UTC) has completed a preprototype PAFC electric utility development program. UTC built and installed a 4.8 MW PAFC power plant at Consolidated Edison in New York City, and supplied a similar unit to Tokyo Electric Company. At ConEdison, the fuel cell and downstream heat recovery equipment never operated as a consolidated system and were shut down in 1984. Knowledge gained from the New York unit, however, was incorporated into the Tokyo system, which was operated successfully. The successor company, International Fuel Cell Corporation (IFC) is currently using data from both locations to address technology improvements and component scale-up for an 11 MW system that is to be used as a basis for the first commercial unit. IFC is soliciting orders for the first of these commercial units at this time.

- Westinghouse is also developing PAFC technology for utility power plants but is in an earlier stage of development than IFC. The present focus of the Westinghouse effort is on verifying development goals and achieving the required performance and endurance levels in small-scale testing prior to size scaleup. The required short term performance has recently been demonstrated in small (10-cell) laboratory stacks. The Westinghouse effort is focused on developing a commercial scale 7.5 MWe powerplant with cofunding from the private sector.

- DOE and the Gas Research Institute (GRI) have cosponsored work to develop fuel cells for commercial and industrial applications. Under this program, UTC has made 46 field-test installations of preprototype 40-kW onsite units for various applications over the past four years. The DOE/GRI test program, scheduled to be completed in 1986, has had cumulative operating hours of over 300,000 as of July 1986. The technical and economic data gathered from this program will be used to determine the most likely markets, applications, and unit design features for a commercial onsite PAFC unit. Further development of technology for PAFC onsite applications is being performed by IFC and by Engelhard Corporation.

The early commercial PAFC power plants are expected to operate on reformed natural gas or distillate fuels. Operation of these power plants with coal would require system modifications such as substitution of a coal gasifier for the reformer, modification of the gas cleanup section, and overall reoptimization to facilitate thermal and fluid integration.

While methane-fueled PAFC power plants are expected to have efficiencies of roughly 45 to 50 percent, molten carbonate fuel cell (MCFC) and solid oxide fuel cell (SOFC) power plants are anticipated to have efficiencies in the range of 55 to 60 percent. MCFC technology is currently in the early development stage and scale-up to full area stacks is in progress. SOFC technology has been tested in single cells and a 5 KW submodule. Molten carbonate and solid oxide fuel cells are not expected to reach the commercialization stage until about the year 2000.

A.7 IN-SITU COAL GASIFICATION

A.7.1 Technology Description

In-situ (underground) coal gasification is similar to other coal gasification processes except that the coal is gasified in place in the ground by injecting steam/oxygen or air into the coal bed. The combustible gases that are produced escape without burning and are collected to form the product gas. The product gas, which has a low-to-medium heating value (depending on the injectant used), can be converted into a number of products, including synthetic natural gas (SNG), methanol, diesel fuel, gasoline, and electricity.

The product gas is formed most efficiently when steam/oxygen (instead of air) is injected to burn the coal so that nitrogen is not introduced as a diluent. The steam provides the hydrogen necessary to complete the reactions and also provides a means of lowering the reaction temperature. The main constituents of the product gas are H_2, CO_2, CO, CH_4, and steam. The exact proportions of these gases vary both with the type of coal and the efficiency of the gasification process.

Several processes can be used to increase the coal's permeability between the steam/oxygen injection and gas production points to a high enough level for effective gas flow rates. These methods include hydraulic fracturing, electrolinking, reverse combustion, and directional drilling. Of these, only reverse combustion and directional drilling have proved practical.

The reverse combustion process involves injecting air into the seam through one well at a high enough pressure to produce a small air flow through the seam to another well, and igniting the coal at the base of this second well. The burn front moves back against the flow to the source of the oxygen creating a highly permeable flow path through the coal. Continued high volume, low pressure injection moves the reaction zone through the coal producing usable gases. One drawback to this method, however, is that at great depths the injection pressures required are so high that the coal near the injection well can ignite spontaneously, making it impossible to complete the link.

Directional drilling has been used successfully to link wells that are physically up to several hundred feet apart. The drill, controlled from the surface, can be made to follow a predetermined path through the coal. Because it allows greater control of the process geometry and greater flexibility, directional drilling is the preferred linking method.

A.7.2 Environmental Characteristics

In-situ gasification technology allows coal to be recovered from otherwise unrecoverable deposits through underground gasification of coal in steeply dipping beds. The medium-Btu product gas containing tars, particulates, and sulfur and nitrogen compounds is transported to the surface, where state-of-the-art gas cleaning methods are used to produce a feed gas for direct burning or for indirect liquefaction in which clean liquid products and synthetic natural gas (SNG) are produced. These fuels have broad market applications.

The primary environmental advantage of underground coal gasification is that it avoids many of the problems of conventional surface mining technologies, in which modern reclamation methods must be used to reduce impacts such as erosion, runoff, infertile and potentially useless land, and altered topographic features. However, surface disturbance can occur and has been experienced in some underground coal gasification testing to date, and is of greatest concern in fairly shallow, thick, flat coal beds. In steeply dipping beds, subsidence is generally less extensive and more manageable.

Surface processing involves extensive gas cleaning to produce a feedstock for catalytic indirect liquefaction, in which essentially all the tars, particulates, and sulfur and nitrogen compounds must be removed to prevent catalyst poisoning. (The gas cleaning techniques used and their ability to recover these compounds are essentially the same as those described under Surface Gasification).

The oxygen and steam required for gasification and surface processing would be generated on-site. The energy needed to produce the oxygen and steam would most likely be satisfied through combustion of tars and the intermediate-Btu product gas. This gas could be combusted prior to cleaning, and flue gas cleanup technologies would have to be used to control SO_2, NO_x, and particulate emissions. It is equally likely that the cleaned synthesis gas would be combusted in an integrated gasifier/combined cycle (IGCC) system.

A.7.3 Status of Development and Work In Progress

The potential advantages of underground coal gasification (UCG) were recognized long ago. The concept was first suggested in 1868 and was outlined technically in 1888. A major field program was initiated in the Soviet Union in 1931. Initial UCG tests in the United States were carried out by the U.S. Bureau of Mines in the 1950s near Gorgas, Alabama. The initial test results, however, were not encouraging and the program was terminated. In 1973, the U.S. government took a renewed interest in UCG field testing. Since then, 27 field tests have been carried out, 22 of which have been funded by the federal government.

In these field tests, sites with dry, strong overburden and at least moderately thick coal have produced the best results to date. Examples include the Hanna, Rawlins, and Centralia tests. Sites with thin coal or wet, weak overburden have produced less favorable results. Examples include the Hoe Creek and Texas tests.

The encouraging technical successes of these tests and of related environmental, theoretical, and laboratory programs have generated increased interest in UCG in the private sector. Basic Resources, Inc., a subsidiary of Texas Utilities, purchased the rights of the extensive Soviet UCG technology in 1975 and, after conducting a number of tests with Texas lignite, is in the planning and permitting phases of an electrical generating demonstration plant (7 MWe capacity). Gulf Oil concluded two successful tests in a steeply dipping coal bed near Rawlins, Wyoming, and is presently considering plans for commercialization. World Energy, Inc., developed plans for a 25-MWe generating facility near Rawlins and submitted these plans to the Synthetic Fuels Corporation for consideration. Currently a consortium of GRI, EPRI, AMOCO and RME are cofunding a further development test near Hanna, Wyoming.

The Lawrence Livermore National Laboratory (LLNL), in cooperation with the Washington Water Power Co. and Pacific Power and Light, has completed a two-phase field test using the Controlled Retracting Injection Point (CRIP) method. This was the first full-scale test of the CRIP gasification method. Developed to minimize the effect of heat losses, the CRIP method adds another control parameter to the process, requiring that a hole be drilled for linkage. To carry the injectant, preferably oxygen/steam, a steel liner is injected through the casing of the injection well until its tip reaches a position near the intersection point with the production well. A movable igniter is inserted into the casing to a desired ignition point, the casing is burned off and the burn cavity grows until it intersects the roof of the seam and the roof begins to collapse; the heat loss to the roof material then begins to reduce the quality of the gas. The injection point is retracted one cavity width and a new burn zone initiated by again burning off a section of the injection liner with the igniter. The coal opposite the burn zone ignites and a new cavity starts to grow. The CRIP method repeats this process to draw the burn step by step back through the coal to the site of the injection well.

The test was conducted in the upper half of a normal 40-foot-thick subbituminous coal seam near Centralia, Washington. The injection well was drilled following the seam some 800 feet from the exposed coal face, where it was intersected by a vertical production well drilled from the surface. Steam/oxygen were used as the injectants.

This process (CRIP) is showing sufficient promise to cause it to be the process of choice for all known tests currently in the planning stage throughout the international community (i.e., India, Belgium, Germany, France, Brazil) and the United States.

A.8 LIQUEFACTION

A.8.1 Technology Description

There are two primary methods of coal liquefaction: (1) indirect liquefaction (coal gasification followed by conversion to liquid fuels); and (2) direct liquefaction (conversion of the complex organic solid structures in coal directly into liquid fuels).

Indirect Liquefaction

Indirect liquefaction involves gasification to produce a raw synthesis gas, gas clean-up, and water gas shift reaction to adjust the H_2:CO ratio of the synthesis gas as required for the synthesis step and the liquid synthesis process itself. A major challenge in the process conception and design is to couple these stages in the most economic, thermally efficient manner.

Coal derived synthesis gas is produced with the highest thermal efficiency by second generation gasifiers (e.g., Slagging Lurgi, Texaco) which use the minimum amounts of oxygen and steam feed. In contrast with the more established gasifiers, the gas so produced has a very low H_2:CO ratio, in the range of 0.6 to 0.7. Because of the dominant contribution of gasification to the total cost of indirect liquefaction, the ideal synthesis reaction would accept such feed ratios directly. Unfortunately, neither traditional Fischer-Tropsch processes nor methanol-forming processes will accept such a low H_2:CO feed ratio. In either case, the water gas shift reaction would first have to be applied to increase the proportion of H_2 present to a H_2:CO ratio of 2 or higher and reject some carbon as carbon dioxide. However, this leads to a loss in thermal efficiency and process simplicity.

The best known approach to indirect liquefaction is the Fischer-Tropsch (F-T) technology which is the basis for the largest commercial liquefaction facilities in the world. These facilities are operated in South Africa by the South African Coal, Oil and Gas Co., Ltd. (SASOL). The new SASOL II and III plants employ dry ash Lurgi Mark IV gasifiers of German design, and fast fluid (entrained recirculating) bed Synthol F-T synthesis reactors developed by SASOL based on technology originally provided by the M.W. Kellogg Co. of the United States. This combination at SASOL is capable of delivering clean fuels including a large percentage of gas and petrochemicals with an efficiency approaching 60 percent. However, 19 percent of the carbon in the coal leaves the dry bottom Lurgi as methane. When the hydrogen and carbon monoxide in the synthesis gas are reacted in the Synthol units, about 23 percent of the output is methane. Additional light gases are formed when the synthesized liquids are upgraded to specification fuels.

When operating at peak efficiency, the dry ash Lurgi/Synthol combination yields over 50 percent of its output as carbon monoxide and hydrogen which are then synthesized to yield an all-liquid output. As a result, the overall thermal efficiency of the SASOL II and III plants is less than 40 percent when producing maximum quantities of liquid fuels.

Since 1983, the Tennessee Eastman Company has operated the only coal-to-methanol plant in the United States. A single Texaco gasifier (plus one back-up) processes 900 tpd of coal to produce methanol as an intermediate in the production of methyl acetate and acetic anhydride.

Direct Liquefaction

Direct liquefaction can be carried out in the presence or absence of catalysts; in a single reactor or in multiple stages; and with or without intermediate removal of solids. Typical operating temperatures range from 820 to 860°F, and typical pressures from 2,000 to 3,000 psig. The ultimate removal of solids (ash and unconverted coal) is an important aspect of all liquefaction processes. Additional processing steps may be required to modify the distribution of primary-process product slate, to achieve fuel specifications, or to mitigate environmental and health concerns associated with the coal liquids.

Major direct liquefaction processes include the Exxon Donor Solvent process, the H-Coal process, and the SRC-I and -II processes.

Exxon Donor Solvent (EDS)

The EDS process liquefies coal in a hydrogen-donor solvent produced in a separate hydrogenation reactor. Pulverized coal slurried in recycled donor solvent is mixed with hot hydrogen and passed through the main (liquefaction) reactor. Recycled process solvent, circulating first through the catalyst vessel, picks up hydrogen atoms and then passes into the liquefaction reactor and "donates" the hydrogen to the dissolved coal -- hence the name "donor solvent."

The products leaving the main reactor are separated. Hydrogen for reuse is recovered from the off-gas through cryogenic separation. An atmospheric distillation step yields a slate of light, middle, heavy distillate, and solid residue fractions. A portion of the middle distillate is used to produce the donor solvent. The residue product proceeds to vacuum fractionation, which yields additional distillate, spent solvent range distillate, and vacuum residue. The residue itself containing unconverted coal and ash may be gasified to produce hydrogen for the liquefaction and cleaner solvent hydrogenation units.

H-Coal Process

The H-Coal Process (developed by Hydrocarbon Research, Inc.) is a direct hydroliquefaction process for converting coal into high quality, clean hydrocarbon liquid fuels. Depending on the operating scheme, the product may be all distillate (syncrude mode) or high production boiler fuel including deashed residue.

The properly sized and dried coal feed is mixed with recycled slurry and process-derived solvent (normally a part of the heavy distillate oil product). The coal/oil slurry, along with part of the recycled hydrogen, is preheated to initiate the coal dissolution, and then introduced to the bottom of an ebullated-bed reactor. The remaining hydrogen feed is preheated and introduced to the bottom of the reactor.

The gas, liquid, and coal/oil slurry are separated and further processed to meet the specifications of the process recycle streams as well as hydrotreated and stabilized to meet commercial specifications. The coal/oil slurry is partially concentrated in a hydroclone system. The hydroclone overflow and portions of the heavy distillate oil are used to slurry the fresh coal feed; further oil recovery and solids concentration from the hydroclone underflow are achieved through vacuum distillation of this stream in the syncrude mode and through solvent precipitation and critical flashing in the fuel oil mode. The vacuum bottoms contain mostly unreacted coal and ash. These vacuum bottoms are gasified (Texaco gasifier) to fill the hydrogen requirements of the process.

Solvent Refined Coal (SRC)

The SRC process is a noncatalytic (thermal) process for converting high-sulfur, high-ash coals to nearly ash-free, low-sulfur fuel. The process has two different modes of operation: SRC-I, which yields a solid fuel; and SRC-II, which yields primary distillate liquid fuels.

In SRC-I, properly sized and dried coal is slurried with a process-derived solvent. The slurry, mixed with hydrogen, is preheated and sent to the reactor. The reactor effluent is sent to the vapor-liquid separation stage. Hydrogen (for recycle), fuel gas, and eventually sulfur are recovered from the primary gaseous stream. Process solvent and other liquid components are removed from the separator slurry, and the remaining slurry is sent to a deashing step in which it is separated into a molten SRC stream and a solid residue stream. The residue stream is then sent to gasification, where it is converted into an inert slag and make-up hydrogen.

SRC-II is a modification of SRC-I, and produces primarily liquid fuels instead of the solid SRC. SRC-II uses proportionally more hydrogen than the

SRC-I process, and also uses a residue containing slurry recycle (ash in the slurry acts as a catalyst) to achieve higher conversion of coal to liquid products. A portion of the ash slurry is removed from the recycle stream and, after fractionating off the distillates, is gasified to fill the hydrogen requirements of the process.

A.8.2 Environmental Characteristics

Indirect Liquefaction

The environmental characteristics of indirect liquefaction processes are essentially similar to the environmental characteristics of surface coal gasification technologies. The environmental benefit of the gasification technologies is that the gaseous sulfur and nitrogen compounds can be removed before combustion or chemical manufacture using either wet scrubbing or high-temperature absorption/adsorption processes.

Hydrogen sulfide removal can be achieved through chemical absorption or physical adsorption after gas cooling or by adsorption on metal oxides at high temperature (1,000 to 1,200°F). These processes can remove more than 99 percent of the gaseous sulfur compounds before combustion of the gases. The sulfur species absorbed in chemical solutions (cold cleanup) can be recovered as elemental sulfur or converted to sulfuric acid. From the metal oxide adsorption process (hot cleanup), the sulfur compounds can be recovered as sulfur or converted to sulfuric acid or solid sulfates (such as calcium sulfate), which can ultimately be disposed of by landfilling.

In addition, sulfur compounds can be captured within the gasifier through the addition of limestone (or dolomite). Capture levels of approximately 90 percent are possible using this method and further capture ("polishing") can be achieved by treating the fuel gas with a metal oxide adsorption process to exceed 99 percent total sulfur removal.

Nitrogen compounds (principally ammonia) are generated in the gasification process and, depending on the gasifier operating temperature, are contained in varying amounts in the fuel gas. The highest ammonia levels are produced in the lowest temperature reactor -- fixed-bed gasifiers; lesser amounts are produced in fluid-bed reactors; and the lowest amount in entrained reactors (which have the highest operating temperature). The nitrogen compounds are easily removed in cold cleanup systems by dissolution in waste and are subsequently recovered as saleable ammonia for fertilizer applications. After cold cleanup, fuel gas contains a small enough level of ammonia that, upon combustion, the NO_x emission is far below NSPS emission limits. With hot gas cleanup systems, the ammonia passes through into the final fuel; thus, NO_x emissions must be controlled by combustion modifications or external de-

NO_x processes. In either treatment, the fuel gas can meet current NSPS limits.

The principal solid waste from the gasifier is coal ash, which can be disposed of in the same manner as coal-fired boiler ash. When limestone is injected into the gasifier, the solids will contain calcium sulfides. It will be necessary to oxidize these solids to convert sulfides to sulfates, which are inert and can be landfilled.

Catalytic synthesis of liquid products such as methanol or F-T products creates no significant emissions. The unreacted tail gas (mostly CO) can be burned in the turbine with steam bottoming. The emissions aspects are similar to those of other IGCC systems (see Gasification); however, since cold cleanup systems must be used to eliminate essentially all sulfur, nitrogen, and particulate matter (which will poison the synthesis catalyst), the tail gas being fired to the combustor is also free of these compounds. Thus, the exhaust gases from the turbine/boiler will be low in NO_x (below NSPS) and sulfur and will be particulate-free. Stored methanol can be burned for peaking or can be sold for transportation fuel applications. Methanol combustion in turbines has been used by utilities; the process is very low in NO_x emissions as well as being free of sulfur and ash. F-T products can substitute as refinery feed and produce conventional products with very low S and N emission potential.

Direct Liquefaction

Direct liquefaction technologies generally involve hydrocracking of the coal molecules, either thermally or catalytically, to produce smaller molecules. These smaller molecules can then be upgraded to specification fuels where essentially all heteroatoms (N, S, O) are removed by reaction with hydrogen, and the particulate matter is eliminated.

Emissions from the plants themselves can be reduced to very low levels through proper design. Sulfur is converted to saleable elemental sulfur, oxygen in the coal is generally reacted with H_2 to form water, nitrogen is hydrotreated to form saleable NH_3, and mineral matter ends up in a bottoms product that is used to produce hydrogen in a gasifier or burned in a boiler. In either case, the mineral matter is converted to a refractory-like slag or fly ash products that are expected to be nonhazardous. Wastewater treatment technologies, such as those used in refineries or in coal gasification plants, can be used to eliminate nearly all phenols, NH_3, and other compounds. The plant can be designed to reuse the wastewater (zero discharge) with blowdowns evaporated to small quantities of solid salt products that can be disposed of at approved disposal sites.

Coal liquefaction technologies provide liquid fuels from coal for a wide variety of market applications. Both direct and indirect liquefaction can be used to produce finished fuels that are virtually indistinguishable from petroleum products.

A.8.3 Status of Development and Work in Progress

Indirect Liquefaction

Primary objectives of the DOE Indirect Liquefaction Program are: (1) to achieve more selective and economic yields of liquid fuels and (2) to achieve better utilization of coal derived gas feedstock.

To achieve its primary objectives, the program supports research which identifies and investigates processes based on:

a. New catalysts able to utilize low hydrogen/carbon monoxide syngas, thereby taking advantage of the new, efficient gasifiers now under development in the U.S.

b. New or modified catalysts with the selectivity to produce desirable liquids either in a single stage or via chemical intermediates in a two-state process.

c. Thermally efficient reactors with improved temperature control and heat recovery compared with reactors currently available for this type of reaction.

Successful research will permit a significant reduction in the cost of each of the following major process areas downstream of the coal gasification step:

a. Clean-up and shift of the new syngas to provide required feedstock for synthesis.

b. Recycle of gas to the reactor to maintain proper gas composition and reactor temperature.

c. Conversion of syngas feedstock to desirable liquids.

d. Separation and refining of produced liquids to marketable products.

The broad based research program now in place includes laboratory scale research into the mechanisms of known catalyst components and into new catalyst systems with higher selectivity, stability, resistance to poisoning, and overall productivity. Projects also are underway at lab scale to develop data required to realize the technical and economic potential of performing the synthesis reaction in a liquid. Multi-phase reactors are used for this research and for hydrodynamics studies of advanced reactor designs.

Two process concepts have been scaled up from laboratory scale for further development and evaluation in proof-of-concept facilities. The larger is an international project with a pilot plant located in West Germany. The plant uses an advanced fluid bed reactor system to convert 100 barrels a day of methanol very efficiently to high octane gasoline. This operation has been successfully completed and a second mode of operation to produce light olefins for conversion to diesel fuel and/or gasoline was completed in 1986.

The second proof-of-concept development effort involves the production of methanol from a simulated coal derived synthesis gas. The facility which produces about 35 barrels per day of methanol using a liquid phase reactor system has operated successfully in a single pass mode utilizing carbon monoxide-rich synthesis gas at La Porte, Texas.

Direct Liquefaction

The technical viability of direct coal liquefaction has been demonstrated. Processes capable of producing the entire slate of liquid fuels currently derived from petroleum crude are available. However, those processes that are ready for commercialization are highly capital-intensive, and are currently not economically competitive with petroleum-derived fuels. Therefore, new process concepts or substantial improvements to existing approaches are necessary before the technology can achieve economic viability.

DOE's Coal Liquefaction Program has identified the improvements that the "advanced" processes must show to become more economically competitive. These targets are:

- Achieve 10 to 15 percent higher yields than those achieved by already demonstrated processes
- Realize up to 30 percent savings in capital and operating costs through improvements in ease of operation and reductions in process severity and complexity
- Reduce heteroatom content by 40 to 50 percent and/or increase the hydrogen content in the liquid product by 10 percent compared to already demonstrated processes
- Implement process modifications or new process concepts capable of producing liquid products that are comparable in bioactivity to their. petroleum analogs.

Major work in progress with "advanced" processes or new concepts in direct liquefaction supported by DOE includes:

- ITSL Process -- Among the "advanced" processes currently being studied, the Integrated Two-Stage Liquefaction (ITSL) process is one that has recently generated significant interest. This process is being investigated at the Advanced Coal Liquefaction R&D Facility in Wilsonville, Alabama. This experimental facility, which is a DOE-industry joint effort, houses three process units: a Thermal Liquefaction (TL) unit; a Critical Solvent Deashing (CSD) unit; and a catalytic hydrogenation or Hydrotreater (HTR) unit.

- Coprocessing of Coal/Petroleum Residual Oil -- Another process concept under evaluation is coal/petroleum residual oil coprocessing.

  By using petroleum based process solvent, coprocessing is expected to reduce substantially the cost of the direct liquefaction process by reducing the complexity of the system. This is accomplished by eliminating the component required for producing a process derived solvent and recycling the solvent back to the liquefaction reactor. The use of existing petroleum refining technology and facilities, which will accelerate the introduction of coal-derived fuels into the marketplace, is expected to reduce the capital costs involved.

A.9 INDUSTRIAL PROCESSES

A.9.1 Technology Description

The industrial sector of the energy-consuming market place offers significant potential for the application of energy saving measures and the development of innovative approaches or technologies to use coal as a more efficient and environmentally responsive energy option. This potential is created by two somewhat independent but closely related factors. The first factor is the amount of oil the industrial sector consumes: 9.3 quads (1980 estimate), second only to the transportation sector in oil consumption. The majority of this oil is consumed in applications not dependent upon any physical attributes of oil other than its heating value and comparative cost. Coal can become a serious competitor in industrial applications if its energy can be supplied at a cost equal to or less than the oil currently being used.

The second factor contributing to the advantageous use of coal in the industrial sector is the potential for technology developments that offer the opportunity for creating innovative solutions (e.g., use of gasification in the direct production of steel in a process that eliminates the need for coke in this industry) to problems that not only confront various sectors of industry but which in some cases threaten their continued existence. These problems are characterized by, but not limited to, environmental concerns, changes in market demand (in which some products no longer sell and new products are demanded), obsolete manufacturing methods, rising energy costs, and threat of imports. In many of these areas, the availability of coal through imaginative applications of new technologies or a process modification can reverse the established trends and become a means of revitalizing these industries. This capability is exemplified in the following description of a new process being developed for the production of iron.

- The process developed by Korf Engineering (a West Germany Company), replaces the two-step coke oven/blast furnace approach to producing pig iron from iron ore and metallurgical coal with an integrated two component oxygen-blown blast furnace system capable of operation on a variety of U.S. coals. The system consists of an upper "reduction shaft" and a lower "melter-gasifier" component. Iron ore, along with an appropriate flux (e.g., limestone), is fed into the top of the reduction shaft where it is reduced to sponge iron by the off-gas from the lower melter-gasifier section into which it is then introduced along with the coal. The lower section is an oxygen-blown fluidized-bed coal gasifier. In this section the sponge iron is melted and the resulting pig iron and slag are separated and tapped as in a blast furnace. The low/medium-Btu, sulfur-free off-gases from the process (sulfur is captured by the limestone and remains in the slag) is scrubbed to remove particulates and is available for site use.

A.9.2 Environmental Characteristics

One of the motivating factors leading to the development of new industrial processes is the need for these processes to be responsive to increasing concerns over environmental issues. This response is being reflected in process changes and technology developments that will reduce any associated environmental impact to the maximum degree possible. While the type of improvement will be process and site specific, the purpose and impact is demonstrated by using the example described above. The direct reduction process for making pig iron from iron ore replaces the three conventional processes of coke-making with a closed system that has two components. A large portion of the fugitive air emissions normally produced by those processes is eliminated, resulting in substantial improvements in the environmental impact of these technologies.

Coke-making has been identified as a source of air, water, and solid waste pollution. Sintering and blast furnaces also emit pollutants. In the direct reduction process of the type proposed which eliminates the need for coke, many of the organic species are decomposed in the reaction vessels, and the by-product gases are scrubbed in a gas scrubber before on-site consumption or flaring, greatly reducing air emissions.

Water effluent from the direct reduction process are generated from blowdown or recycled water from the gas scrubber. These effluents are similar to those from a blast furnace, and can be treated by advanced treatment methods that remove phenols and other organics. The primary solids generated in direct reduction are slag, which may be saleable, and nonhazardous sludge from gas scrubbing, which can be safely discarded.

A.9.3 Status of Development and Work in Progress

A brief review of industrial activity makes it apparent that the industrial sector recognizes both the need and the potential for new processes that are more energy efficient and environmentally responsive. While it is not possible to list even a portion of these activities, the length of the development cycle as well as the magnitude of the effort required can be demonstrated by outlining the steps associated with the development of the direct reduction process.

The direct reduction process developed by Korf Engineering GmbH of West Germany, is based on small-scale tests conducted from 1975 through 1978. In

1979, Korf Engineering GmbH and Voest-Alpine AG initiated joint developmental work, and in 1981 placed in operation a 66,000 ton per year (tpy) pilot plant at Kehl, West Germany, next to the Korf-owned Badische Stahl Werke. Following shakedown, the pilot plant has demonstrated the capability of operating on a wide range of coals, lignite and coke. Iron materials tested included lump ore, pellet, sponge iron, and sinter. The pilot plant facility also included units for gas cleaning and effluent treatment.

In October/November, 1984, the pilot plant was operated on one U.S. core and minntac pellets under the sponsorship of the Department of Energy, the Bureau of Mines, the American Iron and Steel Institute, the State of West Virginia, and the State of Minnesota. The 16-day test run was directed by Korf Engineering GmbH, with the support of operating personnel from Voest-Alpine AG. The test run was monitored by a technical team representing the sponsors, and the team had full access to the pilot plant operations throughout the test run. The purpose of the test run was the evaluation of the performance, stability and reliability of the process for ironmaking. The pilot plant operated quite reliably over the 16-day test period and successfully demonstrated the reliability of the system and its components.

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APPENDIX B: PROPOSAL SUMMARIES

This appendix contains brief descriptions of the 51 submissions received in response to the Program Opportunity Notice. The following information is presented for each submission:

- Proposer
- Project Title
- Project Location
- Technology
- Application
- Product
- Type of Coal Used
- Project Size
- Project Starting Date
- Project Duration
- Cost Sharing
- Proposed Co-Funder(s)
- Brief Descriptive Summary

Indices for the submissions listed alphabetically and by proposal number preface the proposal summaries.

The phrase "identified but proprietary" is used in instances where information is identified by the offeror but is claimed to be proprietary.

INDEX OF PROPOSALS
SORTED ALPHABETICALLY BY OFFEROR

BREVIATED
TLE OF PROJECT:

AL GASIFICATION/POWER GEN.
ING TEXAS LIGNITE

INDEX OF PROPOSALS
SORTED BY PROPOSAL NUMBER

PROPOSAL NUMBER:	OFFEROR NAME:	ADDRESS:	ABBREVIATED TITLE OF PROJECT:
11	WISCONSIN ELECTRIC POWER CO.	231 W. MICHIGAN P.O. BOX 2096 MILWAUKEE, WI 53201	PORT WASHINGTON CLEAN ENERGY PROJECT
12	ENERGOTECHNOLOGY CORP.	238 MAIN STREET CAMBRIDGE, MA 02142	DEMO INTEGRATING COAL CLEAN/ FBC/POWER PLANT
13	COLORADO-UTE ELECTRIC ASSOCIATION INC.	P.O. BOX 1149 MONTROSE, CO 81402	NUCLA CFB DEMONSTRATION PROJECT
14	NORTH MARION DEV., INC/MADIFCO	P.O. BOX 1588 FAIRMONT, WV 26554	CLEAN COAL PROJECT
15	CLEVELAND ELEC. ILLUMINATING COMPANY	55 PUBLIC SQUARE P.O. BOX 5000 CLEVELAND, OH 44101	COMPRESSED AIR ENERGY STORAGE
16	DOW CORNING CORPORATION	P.O. BOX 994 MIDLAND, MI 48686	DEMO & COMML SILICON ALLOY MFG.
17	NOXSO CORPORATION	P.O. BOX 586 LIBRARY, PA 15129	NOXSO PROCESS DEMONSTRATION
18	STIRLING ENERGIES, INC.	P.O. BOX 3354 BECKLEY, WV 25801	COAL BENEFICIATION
19	M.W. KELLOGG COMPANY	THREE GREENWAY PLAZA HOUSTON, TX 77046	THE APPALACHIAN PROJECT
20	ENERGY INTERNATIONAL, INC.	P.O. BOX 66 GULF LAB ROAD CHESWICK, PA 15024	UCG/CLEAN FUELS PROOF-OF-CONCEPT PROJECT

INDEX OF PROPOSALS
SORTED BY PROPOSAL NUMBER

PROPOSAL NUMBER:	OFFEROR NAME:	ADDRESS:	ABBREVIATED TITLE OF PROJECT:
21	COMBUSTION ENGINEERING, INC.	1000 PROSPECT HILL ROAD WINDSOR, CT 06095	CLEAN COAL DEMO FOR U.S. ELEC. POWER INDUSTRY
22	WEIRTON STEEL CORPORATION	400 THREE SPRINGS DRIVE WEIRTON, WV 26062	KR IRONMAKING DEMO PLANT
23	UNIVERSITY OF FLORIDA	ICAAS--SSRB GAINESVILLE, FL 32611	INDUSTRIAL SCALE CLEAN COAL TECH DEMONSTRATION
24	WESTERN ENERGY COMPANY	16 EAST GRANITE BUTTE, MT 59701	ADVANCED COAL CLEANING AND PROCESSING
25	OHIO ONTARIO CLEAN FUELS, INC.	2540 JENNIFER DRIVE POLAND, OH 44514	COAL-PETROLEUM COMPRESSING PLANT
26	TRW, INC.	UTILITY DEMONSTRATION UNIT ONE SPACE PARK REDONDO BEACH, CA 92078	ADVANCED SLAGGING COMBUSTOR UTILITY DEMONSTRATION
27	COMMUNITY CENTRAL ENERGY CORP.	1220 NORTH WASHINGTON AVENUE SCRANTON, PA 18509	FBC OF WET CULM FINES
28	(PROPOSAL NUMBER NOT USED)		
29	UNITED COAL COMPANY	P.O. BOX 1280 BRISTOL, VA 24203	COAL WASTE RECOVERY-ADV TECH DEMONSTRATION
30	DRAVO WELLMAN COMPANY	4800 GRAND AVENUE PITTSBURGH, PA 15225	COMMERCIALIZATION OF BATTELLE TREATED COAL
31	SANITECH, INC.	1935 EAST AURORA ROAD TWINSBURG, OH 44087	DEMO OF DOE-SANITECH TRAVELING GRATE COAL GASIF. PROCESS

INDEX OF PROPOSALS
SORTED BY PROPOSAL NUMBER

PROPOSAL NUMBER:	OFFEROR NAME:	ADDRESS:	ABBREVIATED TITLE OF PROJECT:
32	COMMUNITY CENTRAL ENERGY CORP.	1220 NORTH WASHINGTON AVENUE P.O. BOX 1434 SCRANTON, PA 18509	CLEAN COAL TECHNOLOGY PROJECT
33	ATLANTIC RESEARCH CORPORATION	5390 CHEROKEE AVENUE ALEXANDRIA, VA 22312	ARC CLEAN COAL PROJECT
34	ENERGY & ENVIRONMENTAL RESEARCH CORPORATION	18 MASON IRVINE, CA 92718	GAS REBURNING/SORBENT INJECTION
35	CURATORS/UNIV. OF MISSOURI	UNIVERSITY OF MISSOURI COLUMBIA, MO 65211	COLUMBIA CAMPUS POWER PLANT 200,000 PPH MSFBC BOILER PROJECT
36	COAL TECHNOLOGY CORPORATION	700 11TH STREET SOUTH NAPLES, FL 33940	ADVANCED CCT IN SECONDARY RECOVERY
37	ZTEK CORPORATION	400-2 TOTTEN POND ROAD WALTHAM, MA 02154	POWER PLANT USING SOLID OXIDE FUEL CELLS WITH GASIFIER
38	COAL TECH CORP.	P.O. BOX 154 MERION, PA 19066	ADVANCED CYCLONE COMBUSTOR DEMONSTRATION
39	SOUTHWESTERN PUBLIC SERV. CO.	P.O. BOX 1261 AMARILLO, TX 79170	CIRCULATING FLUIDIZED BED REPOWERING
40	RECOVERY SYSTEMS, LIMITED	1200 JORIE BLVD. OAKBROOK, IL 60521	POST COMBUSTION CLEANUP/SOx/NOx REMOVAL/PHOSHATE BY-PRODUCT
41	PPG INDUSTRIES, INC.	P.O. BOX 1000 LAKE CHARLES, LA 70602	PHOSPHORIC ACID FUEL CELL SYSTEM USING COAL-DERIVED GAS
42	MCDONNELL DOUGLAS ENERGY SYST. INC.	10509 TIMBERWOOD CIRCLE LOUISVILLE, KY 40223	ADVANCED PHYS. CCT (MICROBUBBLE FLOTATION)

INDEX OF PROPOSALS
SORTED BY PROPOSAL NUMBER

PROPOSAL NUMBER:	OFFEROR NAME:	ADDRESS:	ABBREVIATED TITLE OF PROJECT:
43	WESTINGHOUSE ELECTRIC CORP.	ADVANCED ENERGY SYSTEMS DIV. P.O. BOX 158 MADISON, PA 15663	CLEAN COAL FUEL CELL TECH. PROGRAM
44	CHEMCOAL ASSOCIATES	12800 SHAKER BLVD. CLEVELAND, OH 44120	CHEMCOAL PROCESS TECHNOLOGY
45	TENNESSEE VALLEY AUTHORITY	400 WEST SUMMIT HILL DRIVE KNOXVILLE, TN 37902	LIME SPRAY DRYER DRY FLUE GAS
46	QUESTAR SYNFUELS CORPORATION	141 EAST FIRST SOUTH SALT LAKE CITY, UT 84147	UTAH CLEAN COAL PROJECT
47	TENNESSEE VALLEY AUTHORITY	NATIONAL FERTILIZER DEV. CTR. MUSCLE SHOALS, AL 35660	ONCE-THROUGH METHANOL PROJECT
48	GENERAL ELECTRIC COMPANY	INEUMANN WAY CINCANNATI, OH 45215	INTEGRATED GASIFICATION-STEAM INJECTED GAS TURBINE
49	FMC CORPORATION	1501 WOODFIELD ROAD SCHAUMBURG, IL 60195	DRY INJECTION FLUE GAS DESULF. TEST PROGRAM
50	(PROPOSAL NUMBER NOT USED)		
51	NATIONAL LIME ASSOCIATION	3601 N FAIRFAX DRIVE ARLINGTON, VA 22201	USE OF COMM. LIME AS SORBENTS
52	CHEMION CORPORATION	HENDERSON, NV 89015	COAL DESULFURIZATION PROJECT
53	CHARWILL	P.O. BOX 418 BORON, CA 93516	SOx NOx REMOVAL SYSTEM AND BYPRODUCT RECOVERY SYSTEM

PROPOSAL 1 - SUMMARY

Proposer:	Elgin-Butler Brick Company
Project Title:	Clean Coal Demonstration Project, Coal Gasification/Power Generation Using Texas Lignite
Project Location:	Elgin, Texas -- Bastrop County
Technology:	Fixed-bed and moving-bed gasification of lignite; physical gas cleaning and desulfurization; use of coal gas and distillate as fuels in dual fuel diesel engines.
Application:	Industrial
Product:	Clean coal-gas and coal distillate.
Type of Coal Used:	Texas lignite, high sulfur bituminous coal.
Project Size:	Coal in 4.0 (ton/hr), gas production 3870-6175 (dscfm), distillate production 464-1087 (lb/hr).
Project Starting Date:	Notification of Go ahead
Project Duration:	42 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
46	54

Proposed Co-Funders: Elgin-Butler Brick Company
Black Sivalls & Bryson, Inc.

BRIEF DESCRIPTIVE SUMMARY:

The Elgin-Butler Brick Company (EBBCO) proposes to demonstrate the commercial feasibility of four clean coal technologies: 1) a fixed-bed gasifier, 2) a moving-bed gasifier, 3) the four-phase separation of raw coal-gas into dust, distillate, aqueous, and gas fractions, along with the desulfurization of the gas fraction, and 4) the use of a desulfurized coal-gas as a primary fuel and coal distillate as a pilot ignition fuel in dual-fuel diesel engines.

The project efforts would be focused on the optimization of the fixed-bed gasifier as used in small industrial applications; the continued development of the moving bed lignite gasifier and on an advanced gas cleaning technology. In this process the raw overhead gasification product gas stream is separated into a relatively dry and tar-free dust, relatively dust and water-free distillate, water, and a dust-and tar-free gas. This separation technology consists of three processing stages: 1) inertial separation of dust from the raw gas, 2) electrostatic precipitation of the distillate fog from the cooled gas, and 3) condensation of moisture in the gas.

The gasification processes proposed convert sulfur in the coal to gas phase sulfur. Once in the gas phase, the sulfur is captured by an alkali followed by aqueous phase oxidation of the sulfur compounds to solid sulfur. The sulfur leaves the process as an inert solid suitable for land fill.

PROPOSAL 2 - SUMMARY

Proposer:	Minnesota Department of Natural Resources
Project Title:	Corex Process Proposal
Project Location:	Mt. Iron, Minnesota -- St. Louis County
Technology:	Production of pig iron from iron ore and coal in a melter/gasifier using the Korf Engineering COREX (or KR) process.
Application:	Industrial
Product:	Metal
Type of Coal Used:	Low volatile coals and coal blends
Project Size:	330,000 tons/yr hot metal
Project Starting Date:	01/01/87
Project Duration:	73 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
53	47

Proposed Co-Funders: State of Minnesota Department of Natural Resources
U.S. Steel Corporation
Iron Range Resources and Rehabilitation Board

BRIEF DESCRIPTIVE SUMMARY:

The "COREX" process, developed by Korf Engineering (a West German company), replaces the two-step coke oven/blast furnace approach to producing pig iron from iron ore and metallurgical coal with an integrated two-component system capable of operation on a variety of U.S. coals. The system consists of an upper "reduction shaft" and a lower "melter-gasifier" component. Iron ore, along with an appropriate flux (e.g., limestone), is fed into the top of the reduction shaft where it is reduced to sponge iron by the off-gas from the lower melter-gasifier section into which it is then introduced along with coal. This lower section is an oxygen-blown fluizided-bed gasifier. In this section the sponge iron is melted and the resulting pig iron and slag are separated and tapped as in a blast furnace. The low/medium-Btu, sulfur-free off-gases from the process (sulfur is captured by the limestone and remains in the slag) is scrubbed to remove particulates and is available for site use.

The proposed project calls for the design and construction of a 330,000 tons (iron) per year demonstration plant at the United States Steel Corporation Minntac taconite processing plant and operation of the plant on a variety of U.S. feedstocks. The size represents a scaleup of five over the pilot plant where the basic process operability on U.S. feedstocks was demonstrated.

PROPOSAL 3 - SUMMARY

Proposer:	Babcock & Wilcox
Project Title:	LIMB Demonstration Project Extension
Project Location:	Lorain, Ohio -- Lorain County
Technology:	Flue Gas Cleanup - LIMB and "Coolside" duct injection of sorbent
Application:	Utility
Product:	Environmental Control Technology
Type of Coal Used:	Medium to high sulfur coal.
Project Size:	105 MWe
Project Starting Date:	09/01/86
Project Duration:	43 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
61	39

Proposed Co-Funders: Babcock & Wilcox Company
Conoco Inc.
State of Ohio
Dravo

BRIEF DESCRIPTIVE SUMMARY:

A two part project is proposed by Babcock & Wilcox for development of retrofit acid rain precursor control technologies. The first part is an extension of ongoing Limestone Injection Multistage Burner (LIMB) testing. Babcock & Wilcox is currently conducting the full-scale demonstration of the LIMB technology on a 105-MWe wall-fired utility boiler in a project cosponsored by the U.S. Environmental Protection Agency and the State of Ohio at Ohio Edison's Edgewater Station in Lorain, Ohio. The objectives of this project are to demonstrate NO_x and SO_2 emissions reductions on the order of 50-60 percent at a capital cost at least $100 per kW less than wet scrubbers. As a result of funding limitations of the existing contract, testing will be restricted to one sorbent and one coal. The results of the project proposed here will broaden the applicability of the LIMB technology by extending the number and types and sorbents to be evaluated.

The second part of the project is to evaluate the Conoco "Coolside" process for SO_2 control. This process involves dry sorbent injection/humidification technology downstream of the boiler. The "Coolside" technology has been tested by Conoco in the laboratory and in a 1 MWe field test at Dupont's Martinsville plant. The proposed demonstration will also be done at the Edgewater Station and provide a side-by-side comparison with LIMB.

PROPOSAL 4 - SUMMARY

Proposer:	American Electric Power Service Corporation
Project Title:	TIDD PFBC Demonstration Plant
Project Location:	Brilliant, Ohio -- Jefferson County
Technology:	Pressurized Fluizided-Bed Boiler
Application:	Electric Utility (New/Retrofit)
Product:	Electricity
Type of Coal Used:	Ohio High Sulfur Bituminous
Project Size:	70 MWe
Project Starting Date:	04/30/86
Project Duration:	76 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
66	34

Proposed Co-Funders: American Electric Power Service Corporation
State of Ohio

BRIEF DESCRIPTIVE SUMMARY:

The American Electric Power Service Corporation (AEPSC), on behalf of the Ohio Power Company, proposes to construct and operate a 70 MWe Pressurized Fluidized-Bed Combustion (PFBC) Combined Cycle Demonstration Plant in Brilliant, Ohio, located on the Ohio River approximately 76 miles downstream from Pittsburgh, Pennsylvania. The project will utilize technology developed by ASEA-PFB and marketed in the U.S. by ASEA Babcock PFBC (a joint venture between ASEA and Babcock & Wilcox). The combined cycle plant will operate at 1,580°F and a pressure of 12 atmospheres with off-gases expanded through a ASEA STAL GT120 gas turbine with a steam turbine bottoming cycle. The demonstration plant will be retrofitted into a moth-balled coal-fired power plant and will utilize the existing steam turbine and other site utilities.

PROPOSAL 5 - SUMMARY

Proposer:	Pennsylvania Coke Technology, Inc.
Project Title:	PACTI Coke/Power Production Systems Technology
Project Location:	To be identified
Technology:	Coal gasification.
Application:	Gas cleaning and power generation.
Product:	Coke, clean gas for power generation.
Type of Coal Used:	Pennsylvania and West Virginia metallurgical coals.
Project Size:	Coke - 200,000 tons/year, energy - 13 MWe.
Project Starting Date:	9/15/86
Project Duration:	45 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
53	47

Proposed Co-Funders: Pennsylvania Coke Technology, Inc.
ENI Engineering Co.
Westinghouse Electric Corporation
Consolidation Coal Company
Kaiser Engineering Company
State of Pennsylvania

BRIEF DESCRIPTIVE SUMMARY:

The technology proposed by Pennsylvania Coke Technology, Inc., (PACTI) and its sponsors produce both coke and electric power. The coke ovens are of a special design to minimize their complexity and cost, operating under negative draft pressure to prevent the escape of unhealthy hydrocarbon pollutants. Desulfurization apparatus are used to remove SO_2 from the combustion product gases. Heat recovery steam boilers and associated steam turbine generators are used to produce electric power. New Source Performance Standards for SO_2, NO_x, and particulates equivalent to those for conventional power plants are projected to be achieved by a PACTI coke/power plant. The project is designed to produce 200,000 tons of coke per year and generate 13 MWe of electric power utilizing Pennsylvania and West Virginia metallurgical coals. The proposed demonstration facility would be the initial module of an eventual commercial operation which would produce 600,000 tons per year of coke and 36 megawatts of electrical power.

PROPOSAL 6 - SUMMARY

Proposer:	Consolidation Coal Company/Foster Wheeler Power Systems, Inc.
Project Title:	West Virginia University Clean Energy Project
Project Location:	Morgantown, West Virginia -- Monongahelia County
Technology:	Gasification, Combined Cycle with hot gas cleanup
Application:	Utilities, Cogeneration Plants, Industrial
Product:	Electricity, Steam
Type of Coal Used:	Pittsburgh No 8
Project Size:	30 MWe plus 200,000 pounds/hour steam (250 psia, 555°F)
Project Starting Date:	01/01/87
Project Duration:	36 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50.8	49.2

Proposed Co-Funders: Consolidation Coal Company
Foster Wheeler Power Systems, Inc.
State of West Virginia

BRIEF DESCRIPTIVE SUMMARY:

The Consolidation Coal Company of Pittsburgh, Pennsylvania, and Foster Wheeler Power Systems Corporation of Livingston, New Jersey, have proposed to design, build, and operate an integrated gasification combined cycle power plant in Morgantown, West Virginia. The plant will be designed to convert approximately 500 tons per day of high sulfur West Virginia coal into electric power and steam in an environmentally acceptable manner, while offering significant reductions in capital and operating costs over conventional coal-based technologies. The steam produced will be used in the buildings and laboratories of West Virginia University, replacing three obsolete coal-fired boiler plants. The power will be sold to the Monongahelia Power Company. The proposed system is based on the U-Gas coal gasification process in which the gasification of coal in the presence of limestone for sulfur removal will be accomplished. Hot cleanup of the low-Btu coal gas using ceramic filters and the zinc ferrite desulfurization process will prepare the fuel gas for combustion in a gas turbine combined cycle power plant. The plant would be expected to start operation in late 1989 or early 1990.

PROPOSAL 7 - SUMMARY

Proposer:	American Minerals, Inc.
Project Title:	American Minerals Coal Slurry Reprocessing
Project Location:	Oswego, Kansas -- Cherokee County
Technology:	Physical beneficiation of fines from coal preparation refuse sites with pelletizing of product.
Application:	Upgrading coal refuse for industrial use (cement and power generation).
Product:	Cleaned Coal
Type of Coal Used:	Kansas bituminous coal refuse (2-8% sulfur; up to 50% ash)
Project Size:	1,600 tpd feed, 400 tpd product
Project Starting Date:	09/30/86
Project Duration:	84 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
84	16

Proposed Co-Funder: American Minerals, Inc.

BRIEF DESCRIPTIVE SUMMARY:

The proposed project is a coal recovery process utilizing a wet gravity system to reclaim coal from old abandoned coal slurry ponds in the State of Kansas. The primary components performing the coal separation task are spiral concentrators that separate the pond refuse into two products, one consisting of fine sized coal and some slimes and the other a refuse for discarding to existing strip pits. The coal product is pumped to a dewatering screen for removal of slimes and a majority of the water and from these, the coal passes through a centrifuge dryer. The dryer product is stockpiled prior to blending with crushed limestone and pelletized.

All water and refuse streams are directed to a common refuse sump to be pumped back to strip pits and excavated ponds for back filling and water reclamation. Any slurry spills within the plant and drainage from the coal stockpiles will flow by gravity to a ground level sump and be pumped to the refuse sump for final disposal and water reclamation. The components of the system consists of: spiral concentrators, desliming pumps, centrifuge dryers, dewatering screens, pumps, dredge, etc. The proposed project will process 1,600 tpd of feed and produce 400 tpd of product coal and is claimed to reduce ash from 45 percent to under 10 percent with nominal sulfur reduction from the 3-5 percent sulfur in the feed. The final product will be pelletized for sale.

PROPOSAL 8 - SUMMARY

Proposer:	City of Tallahassee
Project Title:	Arvah B. Hopkins Station Unit 2 Circulating Fluidized-Bed Replacement Boiler
Project Location:	Tallahassee, Florida -- Leon County
Technology:	LURGI Circulating Fluidized-Bed Combustor
Application:	Utility
Product:	Electricity
Type of Coal Used:	Various U.S. coals, design basis is West Virginia high sulfur coal.
Project Size:	250 MWe
Project Starting Date:	10/01/86
Project Duration:	52 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
73	27

Proposed Co-Funder: City of Tallahassee, Electric Department

BRIEF DESCRIPTIVE SUMMARY:

The City of Tallahassee proposes to retrofit the existing gas/oil fired Hopkins Unit 2 boiler into a coal fired 235 MW steam electric power plant by using a circulating fluidized-bed boiler which will produce steam to drive an existing turbine generator. The new combustor will fire West Virginia bituminous coal. Contractors include R.W. Beck & Associates as consultants, Bechtel as the engineer/construction manager, Combustion Engineering/Lurgi as the boiler supplier, and Westinghouse as the turbine consultant.

The project will be located three miles west of the City of Tallahassee at a power station which does not currently have coal burning units.

PROPOSAL 9 - SUMMARY

Proposer:	Calderon Energy Company
Project Title:	Commercial Demonstration of Air Blown, Pressurized, Fixed-Bed Slagging Coal Gasification with Regenerative Hot Gas Cleanup Tied to Combined Cycle Power Generation
Project Location:	Bowling Green, Ohio -- Wood County
Technology:	Air-blown pressurized, fixed-bed slagging coal gasification with regenerative hot gas stream cleanup
Application:	Combined cycle power generation/cogeneration
Product:	Electricity and Steam
Type of Coal Used:	Identified but proprietary
Project Size:	25 tons/hr coal; 50 MWe
Project Starting Date:	06/01/86
Project Duration:	72 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
Identified but proprietary	

Proposed Co-Funders: Calderon Energy Company
State of Ohio
City of Bowling Green

BRIEF DESCRIPTIVE SUMMARY:

The Calderon process utilizes technical methodology based on steel industry coke making techniques to produce a clean low-Btu fuel gas that can be burned directly in an integrated combined cycle power generation system. In the process the raw fuel gas is produced through devolatilization of the coal and subsequent gasification of the resultant coke. More than 93 percent of all sulfur compounds are removed from the raw fuel gas through the use of a new proprietary hot gas cleanup process. In this single step process the desulfurizer is regenerable and it is capable of minimizing energy losses while avoiding any tar handling problems. Babcock & Wilcox, a McDermott Company, will design, construct, and test the proposed 50 megawatt facility on a turnkey basis for Calderon Energy Company. Babcock & Wilcox also will continue to operate this facility under a separate service contract to provide energy for the electrical needs of the city of Bowling Green, Ohio.

PROPOSAL 10 - SUMMARY

Proposer:	University of Cincinnati
Project Title:	Swirling Circulating Fluidized-Bed Technology
Project Location:	Cincinnati, Ohio -- Hamilton County
Technology:	Swirling Circulating Fluidized-Bed Combustion
Application:	Industrial, Commercial
Product:	Steam
Type of Coal Used:	Ohio #6
Project Size:	100,000 pounds/hour of steam
Project Starting Date:	08/11/86
Project Duration:	36 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders: University of Cincinnati
Ohio Coal Development Office

BRIEF DESCRIPTIVE SUMMARY:

The University of Cincinnati proposes to demonstrate a proprietary Swirling Circulating Fluidized-Bed Boiler for burning high sulfur coal in compliance with environmental emission standards. It is a modification of the circulating fluidized-bed technology. The boiler designed for producing 100,000 lbs/hr of steam will be installed on the east campus. The specific objectives of the demonstration are to demonstrate technical and environmental performance using high sulfur coal, obtain erosion data, and develop comparisons with current boiler technologies. It is expected that the proposed technology will be commercialized by 1992.

PROPOSAL 11 - SUMMARY

Proposer:	Wisconsin Electric Power Company
Project Title:	Port Washington Clean Energy Project
Project Location:	Port Washington, Wisconsin -- Ozaukee County
Technology:	Pressurized Fluidized-Bed (Turbocharged) Boiler
Application:	Utility-Size New/Retrofit Steam Generator
Product:	Electricity
Type of Coal Used:	Midwestern high sulfur
Project Size:	80 MWe
Project Starting Date:	09/01/86
Project Duration:	84 months
Cost Sharing:	

Average Participant Share (%)	Average DOE Share (%)
50.1	49.9

Proposed Co-Funders:
Wisconsin Electric Power Company
Gilbert Commonwealth
BBC Brown Boveri Inc.
Foster Wheeler Corporation
Cottrell Environmental Sciences
Electric Power Research Institute

BRIEF DESCRIPTIVE SUMMARY:

Wisconsin Electric Power Company, in association with Gilbert/Commonwealth, BBC Brown Boveri, Inc., Foster Wheeler Corporation, Research-Cottrell, a construction contractor, and the Electric Power Research Institute have proposed to design, construct and test a turbocharged pressurized fluidized-bed combustion (PFBC) system by retrofitting Wisconsin Electric Power Company's 80 MW Unit 5 at Port Washington, Wisconsin. An existing coal-fired boiler, which does not have any SO_2 abatement equipment, will be replaced by a turbocharged PFBC system that can further reduce the presently low NO_x emissions and achieve at least 90 percent sulfur capture. The retrofitted plant will burn coal containing as much as 4 percent sulfur in an environmentally acceptable manner.

The turbocharged pressurized fluidized-bed boiler is to generate electricity through a steam cycle. The boiler will operate at 6 to 10 atmospheres of pressure in a fluidized, bubbling bed mode in the presence of dolomite to control sulfur dioxide emissions. The bed operates at 1,650°F with heat extraction in-bed and above the bed to yield an exit gas temperature of 725°F. The exit gases are expanded through a turbo-compressor which provides the fluidization air to the boiler. The modular boiler design represents an "early entry" pressurized boiler which can be installed in new or retrofit applications of high sulfur coal combustion for electricity production.

PROPOSAL 12 - SUMMARY

Proposer:	Energotechnology Corp.
Project Title:	Demonstration Project Integrating Simple Coal Cleaning Pulverized Coal and Firing Fluidized-Bed Combustion in a Novel Power Plant Steam Cycle.
Project Location:	Rockingham, North Carolina -- Rockingham County
Technology:	FBC and physical coal cleaning
Application:	Utility
Product:	Electricity
Type of Coal Used:	Variety of Eastern coals
Project Size:	60 tons per hour coal feed (Duke Power Company's Dan River Unit No. 3)
Project Starting Date:	09/30/86
Project Duration:	60 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
98.1	1.9* (or 49.5 of Phase I)

*NOTE: Offeror will decide whether to proceed with Phases 2 and 3 following completion of Phase I and indicated that additional federal funding may be required if he proceeds with Phases 2 and 3.

Proposed Co-Funders: Energotechnology Corporation
North Carolina Alternate Energy Corporation

PROPOSAL 17 - SUMMARY

Proposer:	NOXSO Corporation
Project Title:	NOXSO Process Demonstration
Project Location:	Toronto, Ohio -- Jefferson County
Technology:	Simultaneous SO_2/NO_x Flue Gas Cleanup Using Dry Sorbent in a Fluidized-Bed, Regenerable Process
Application:	Utility - new and retrofit
Product:	Environmental Control
Type of Coal Used:	Ohio bituminous (3.7% sulfur)
Project Size:	5 MWe (10,000 scfm of flue gas)
Project Starting Date:	10/01/86
Project Duration:	24 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders:
NOXSO Corporation
Ohio Edison Company
Davison Division of W.R. Grace
Ohio Department of Energy

BRIEF DESCRIPTIVE SUMMARY:

In the NOXSO process as commercially envisioned, flue gas from coal combustion operations, prior to treatment for particulate removal, is passed through a fluidized-bed of dry solid sorbent for the simultaneous removal of both SO_2 and NO_x. The sorbent used for pollutant removal is a commercially marketed product typically consisting of an alumina-type catalyst support which is coated with sodium carbonate. Reaction of both sulfur and nitrogen oxides to achieve 90 percent removal from the flue gas is the target which has been achieved in prior developmental testing of the NOXSO process. The flue gas after treatment for SO_2/NO_x removal, is then processed in a conventional manner for particulate removal prior to stack discharge. The NOXSO process sorbent from the flue gas treatment unit is subsequently processed in a second fluidized-bed reactor for regeneration of the spent sorbent. A typical regeneration sequence consists of heat treatment at evaluated temperatures (e.g., 600°C) and treatment with a reducing gas, such as hydrogen, to produce concentrated nitrogen oxides and hydrogen sulfide gas streams which can subsequently be processed for (1) reduction of the nitrogen oxides to nitrogen and oxygen and (2) conversion of the hydrogen sulfide to marketable byproducts such as sulfur or sulfuric acid.

Development work on the NOXSO process absorber has been conducted at the bench-scale level using a small slipstream of flue gas from an operating coal-fired utility boiler. This work produced data on the process chemistry, kinetics, and performance capabilities of the sorbent. Subsequent development work was conducted and is continuing at a scale of approximately 0.75 MW on a coal-fired experimental test facility. This on-going development work is being directed toward optimizing absorber operating conditions and decoupled testing of sorbent regeneration which is then recycled to the absorber unit.

The NOXSO Corporation proposes to design, construct, and operate a continuous demonstration of the NOXSO process. This demonstration facility would represent the first integration of all required NOXSO process modules into a continuous loop and would be operated for optimization of the overall process design. This facility would be constructed at Ohio Edison's Toronto Generating Plant at Toronto, Ohio, and would process a slipstream of the flue gas from that plant at approximately 5 MWe scale. Construction would be followed by a 12-month operational testing program on flue gas produced from combustion of a coal containing 3.6 percent sulfur.

PROPOSAL 18 - SUMMARY

Proposer:	Stirling Energies, Inc.
Project Title:	Coal Beneficiation
Project Location:	Beckley, West Virginia -- Raleigh County
Technology:	Upgrading coal washing facilities, continuous coke making
Application:	Utility, industries
Product:	High grade metallurical and steam coal, metallurgical sized coke
Type of Coal Used:	West Virginia bituminous
Project Size:	Not specified
Project Starting Date:	08/01/86
Project Duration:	64 months
Cost Sharing:	

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funder: Stirling Energies, Inc.

BRIEF DESCRIPTIVE SUMMARY:

Stirling Energies proposes to upgrade an existing coal washing plant so it will have the following capabilities: no liquid discharge, no coal slurry ponds, all reject material will be dewatered and conveyed by belt to controlled storage area, and pelletizing the minus 48 mesh coal into 1-inch sized pellets. With the profits from the commercial coal washing facilities, they propose to carry on research to develop commercial coal processes to produce energy-related products.

PROPOSAL 19 - SUMMARY

Proposer:	The M. W. Kellogg Company
Project Title:	The Appalachian Project
Project Location:	Cairnbrook, Pennsylvania -- Somerset County
Technology:	Intergrated Gasifier Combined Cycle Gas Turbine System with Hot Gas Cleanup
Application:	Utility
Product:	Electricity
Type of Coal Used:	High sulfur, Eastern bituminous, coals
Project Size:	60 MW
Project Starting Date:	10/01/86
Project Duration:	63 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders:

M. W. Kellogg Company
KRW Energy Systems Inc.
Westinghouse Electric Corporation
General Electric Company
Pennsylvania Electric Company (PENELEC)

BRIEF DESCRIPTIVE SUMMARY:

The proposed project is for the purpose of demonstrating an advanced integrated coal gasification combined cycle (IGCC) system. The project will feature the Kellogg-Rust-Westinghouse (KRW) ash agglomerating fluidized-bed gasification process using in-bed desulfurization with advanced "hot gas cleanup" for particulate and sulfur control, and a General Electric MS6001 gas turbine combined cycle power system. One such KRW gasifier operating in the air-blown mode with in-bed desulfurization and hot gas cleanup technology will convert 485 tons per day of bituminous coal into a low-Btu fuel gas for use in an advanced combustion turbine generator, coupled to a heat recovery steam generator. The steam generated from the combustion turbine exhaust and from the gasifier product gas heat recovery will be fed to a steam turbine generator.

The nominal 60 MW demonstration project managed by Appalachian Mountain Coal Development Company (AMCOAL), a special purpose company formed by Kellogg and General Electric to demonstrate and commercialize the technology, will feature a hot gas cleanup system which delivers fuel gas at 1,000°F - 1,200°F to the combustion turbine, thus avoiding costly inefficient low pressure cleanup processes. This is made possible by the use of in-bed desulfurization and a hot-sulfur-removal polishing step which uses a zinc ferrite sorbent bed. Particles will be removed by the use of a sintered metal filter.

The system, once it has been demonstrated, will be highly efficient with heat rates around 7,800 Btu/kWhr at a capital cost of approximately $1,000 per kW. Various sizes can be implemented by using the 60 MW module that will be demonstrated in the overall system. Other applications for the system are cogeneration and retrofit of combustion turbines and gas-fired combined cycles.

PROPOSAL 20 - SUMMARY

Proposer:	Energy International, Inc.
Project Title:	UCG/Clean Fuels Proof-of-Concept Project
Project Location:	Rawlins, Wyoming -- Carbon County
Technology:	Underground coal gasification/indirect liquefaction
Application:	Refiners and market users of substitute natural gas/synthesis gas/distillate liquids
Product:	SNG, Clean Distillate Liquids
Type of Coal Used:	Sub-bituminous, Steeply Dipping Bed Coal Seams
Project Size:	200 tons of coal per day
Project Starting Date:	09/15/86
Project Duration:	36 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
51	49

Proposed Co-Funders:
Energy International Inc.
Stearns Catalytic Corporation
Rocky Mountain Energy Company
WRI
Gas Research Institute

BRIEF DESCRIPTIVE SUMMARY:

A proof-of-concept/pilot demonstration of the U.S. DOE developed Steeply Dipping Bed (SDB) underground coal gasification (UCG) technology applied to the sub-bituminous coal deposits of Wyoming is proposed. The pilot demonstration unit will be at the same general location (Rawlins) as previous tests and will operate for 180 days, gasify 36,000 tons of coal and produce up to 2,000-4,000 barrels of middle distillate liquids using a fixed bed indirect liquefaction technology. The commercial plant to follow (of which the proposed demonstration represents the first module) will produce 4,000 bbl/day of middle distillate transportation liquids and 60,000,000 scf/day of SNG. The proposers include the technical UCG team, formerly with Gulf, the engineering firm (Stearns Catalytic) who has operated several past DOE UCG field tests, and a coal-owner/energy-user (Rocky Mountain Energy).

PROPOSAL 21 - SUMMARY

Proposer:	Combustion Engineering, Inc.
Project Title:	A Clean Coal Demonstration Program for the U.S. Electric Power Industry
Project Location:	Homer City, Pennsylvania -- Indiana County Windsor, Connecticut -- Hartford County Alliance, Ohio -- Stark County
Technology:	Combustion of medium and deep cleaned coals
Application:	Utility
Product:	Cleaned Coal
Type of Coal Used:	8 U.S. coal types
Project Size:	20 tons/hour coal cleaning; testing of eight coal types in two 200 MWe test burns
Project Starting Date:	10/01/86
Project Duration:	36 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders:	Combustion Engineering, Inc. Babcock & Wilcox Inc. Black & Veatch Energy and Environmental Research EPRI

BRIEF DESCRIPTIVE SUMMARY:

This project, essentially, is an extension of the EPRI coal cleaning program. It would add combustion testing of coals, cleaned to different levels at EPRI's existing Homer City, Pennsylvania plant. For the proposed program an initial group of fifteen coals would be selected based on their commercial significance, rank, and mineral matter characteristics. Washability tests will be conducted on the coals to determine their potential for beneficiation. From the initial group, eight coals would be selected and beneficiated to two levels (one "medium" and one "deep" cleaned) in EPRI's Coal Cleaning Test Facility (CCTF) at Homer City, Pennsylvania. Samples, as appropriate, will be provided for testing in the laboratory and in small (4-5 MBtu/hr) test rigs. The work will be accomplished by two boiler companies (i.e., CE and B&W) to permit comparison between tangentially and wall-fired combustion systems and to provide a larger basis for eventual commercialization. Subsequently, four coals would be selected for field testing in 200 MW coal-fired utility boilers. The test would be coordinated by a consulting contractor and the data will be used for a computer models including the Coal Quality Impact Model (CQIM) being developed by Black & Veatch. The CQIM would predict the performance of commercially available cleaned coals with regard to site-specific total plant performance, e.g., pulverization characteristics (mill wear, energy requirements), combustion performance (ignition stability, carbon burnout), fireside performance (slagging, fouling, ash erosion), and emissions (particulate, SO_2, NO_x). Combining results from the CQIM with EPRI's coal cleaning cost model and coal transportation model, cost benefit analyses of improved coal quality on power plant performance can be performed. The model will be validated by comparing predictions and performance in utility boilers using two cleaned coals.

PROPOSAL 22 - SUMMARY

Proposer:	Weirton Steel Corporation
Project Title:	Kohle Reduction (KR) Ironmaking Demonstration Plant
Project Location:	Weirton, West Virginia -- Hancock County
Technology:	Production of pig iron from iron ore and coal in a melter/gasifier using the Korf Engineering KR (or COREX) process
Application:	Industrial ironmaking operations
Product:	Metal
Type of Coal Used:	Low volatile coal and coal blends from West Virginia, Pennsylvania and Ohio
Project Size:	330,000 tons/yr. hot metal
Project Starting Date:	01/01/87
Project Duration:	55 months
Cost Sharing:	

Average Participant Share (%)	Average DOE Share (%)
64.6	35.4

Proposed Co-Funder: Weirton Steel Corporation

BRIEF DESCRIPTIVE SUMMARY:

The Kohle Reduction (KR) process, developed by Korf Engineering (a West German Company), replaces the two-step coke oven/blast furnace approach to producing pig iron from iron ore and metallurgical coal with an integrated two component oxygen-blown blast furnace system capable of operation on a variety of U.S. coals. The system consists of an upper "reduction shaft" and a lower "melter-gasifier" component. Iron ore, along with an appropriate flux (e.g., limestone), is fed into the top of the reduction shaft where it is reduced to sponge iron by the off-gas from the lower melter-gasifier section into which it is then introduced along with the coal. The lower section is an oxygen-blown fluidized-bed coal gasifier. In this section the sponge iron is melted and the resulting pig iron and slag are separated and tapped as in a blast furnace. The low/medium-Btu, sulfur-free off-gases from the process (sulfur is captured by the limestone and remains in the slag) is scrubbed to remove particulates and is available for site use.

The proposed project calls for the design and construction of a 330,000 ton (iron) per year demonstration plant at the Weirton Steel plant in Weirton, West Virginia, and operation of the plant on a variety of U.S. feedstocks. The size represents a scale-up of five over the pilot plant where the basic process operability on U.S. feedstocks was demonstrated.

PROPOSAL 23 - SUMMARY

Proposer:	University of Florida
Project Title:	Industrial Scale Clean Coal Technology Demo
Project Location:	Gainesville, Florida -- Alachua County
Technology:	Use advanced combustor to burn pulverized coal/gas and coal/water slurry - gas mixtures
Application:	Utility, industry
Product:	Steam
Type of Coal Used:	All ranks of coal
Project Size:	Up to 20,000 pph
Project Starting Date:	09/01/86
Project Duration:	36 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders: University of Florida
Gas Research Institute
Peoples Gas
Parker Hannifin
Florida NGA
Florida Gas Transmission

BRIEF DESCRIPTIVE SUMMARY:

The University of Florida proposes to retrofit advanced combustors to existing boilers that are designed for burning oil to enable them to operate on mixtures of coal slurries and gas or pulverized coal and gas. The testing will be carried out at the Sunland Training Center Steam Plant in Gainesville, Florida. The purpose of the project is to demonstrate low cost conversion from oil, while increasing the use of coal and minimizing environmental emissions.

PROPOSAL 24 - SUMMARY

Proposer:	Western Energy Company
Project Title:	Advanced Coal Cleaning and Processing Facility
Project Location:	Colstrip, Montana -- Rosebud County
Technology:	Coal Preparation
Application:	Upgrading Coal Quality
Product:	Coal
Type of Coal Used:	Montana Sub-bituminous and lignite
Project Size:	50 tons/hr
Project Starting Date:	03/01/87
Project Duration:	24 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders: Western Energy Company
Montana Science and Technology Alliance

BRIEF DESCRIPTIVE SUMMARY:

The offerer proposes the demonstration of a novel coal cleaning process coupled with physical coal cleaning techniques to upgrade high moisture, low rank-coals to enhance their transportability to mid-western and eastern coal markets. The major focus will be to enhance the marketability of low-rank western coals, which normally contain moisture content of 25 to 55 percent, sulfur content of 0.5 to 1.5 percent and heating value of 5,500 to 9,000 Btu/lb. The process is expected to produce a stable, upgraded coal product with a moisture content as low as 1 percent, sulfur content as low as 0.3 percent, and heating value up to 12,000 Btu/lb.

The objective of this project is to construct and demonstrate an advanced coal cleaning and processing facility to be located in Colstrip, Montana. The 50 tons per hour unit will be located on Western Energy property adjacent to Montana Power Company Colstrip generating units and will primarily process coal from the Colstrip Station's surge pile.

PROPOSAL 25 - SUMMARY

Proposer:	Ohio Ontario Clean Fuels Inc. Stearns Catalytic Corporation HRI, Inc.
Project Title:	Prototype Coal-Petroleum Coprocessing Plant
Project Location:	Warren, Ohio -- Trumbull County
Technology:	Coal-Petroleum Coprocessing
Application:	All Markets
Product:	Clean Distillate Liquid
Type of Coal Used:	Ohio #5 & #6; Alternate coals may be used
Project Size:	Will process 800 TPD of coal plus sufficient residual oil to yield 11,750 BPD of clean distillate liquid
Project Starting Date:	08/01/86
Project Duration:	52 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
80.1	19.9

Proposed Co-Funders:	Ohio Ontario Clean Fuels Inc. Stearns Catalytic Corporation HRI, Inc.

BRIEF DESCRIPTIVE SUMMARY:

The proposed project is a prototype commercial coal/oil coprocessing plant to be located in Warren, Ohio. This plant will convert high sulfur, high nitrogen, Ohio bituminous coal and poor-quality petroleum residua to produce 11,750 barrels per day of clean liquid fuels. The process to be utilized in the project is Coal/Oil Co-Processing, utilizing HRI's proprietary ebullated-bed reactor technology. In this process clean liquid fuels are produced from coal, petroleum residuum, and natural gas. The ebullated bed H-oil process has been operated commercially. Coal is blended with residual oil in the process and both are simultaneously converted to clean distillate fuels. A "typical" C4-975^{o}F distillate fuel will contain 0.1 percent sulfur and 0.2 percent nitrogen. The prototype plant will process 800 tons per day of coal, plus residual sufficient to yield 11,750 barrels per day of distillate product.

PROPOSAL 26 - SUMMARY

Proposer:	TRW, Inc.
Project Title:	Advanced Slagging Coal Combustor Utility Demonstration
Project Location:	Orange & Rockland's Lovett Station (NY) -- Rockland County
Technology:	Advanced slagging combustor
Application:	Utility and industrial boilers; retrofit and new; conversions of oil and gas boilers to coal
Product:	Steam and/or electricity
Type of Coal Used:	West Virginia and Kentucky 0.7% bituminous coals supplemented by 2.5% S Ohio coal tests at the Cleveland site.
Project Size:	69 MWe
Project Starting Date:	01/01/87
Project Duration:	36 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
51	49

Proposed Co-Funders:
TRW, Inc.
Orange and Rockland Utilities
Stone and Webster
Joy-Niro
State Of Ohio
State of New York

BRIEF DESCRIPTIVE SUMMARY:

The TRW advanced slagging coal combustor can be retrofitted to existing coal, oil, and, perhaps, gas-designed boilers. It can fire a wide variety of coals in either dry or slurry form. Approximately 90 percent slag rejection is achieved in the combustor, thus reducing ash carryover to the boiler. Staging of the combustion air permits NO_x to met the NSPS. The sulfur removal concept proposed here involves limestone injection into the combustor gases exhausting into the boiler, much like in the LIMB process. The principal difference is that the combustion of a coal particle and ash rejection is accomplished external to the boiler at substoichiometric conditions. The claimed result is low NO_x, improved SO_2 capture (compared to LIMB), and reduced slagging/fouling in the boiler, making the technology a potentially attractive retrofit for coal or oil designed boilers. TRW also proposes a tail-end spray dryer enhancement which could be used in conjunction with the slagging combustor to achieve NSPS SO_2 reductions. The spray dryer would operate on recycled unreacted lime, and since ash is largely removed in the combustor, it will not build up as rapidly in the recycle system. This option would permit SO_2 control to the MSPS level at low Ca/S ratios.

The proposed demonstration at the Orange and Rockland Utilities, Lovett Station, Lovett, New York will expand the industrial data base from the ongoing 40 MBtu/hr TRW industrial boiler demonstration in Cleveland and provide scaleup data to 69 MWe (with multiple (4) combustors, each of which is sized at 160 MBtu/hr) as well as utility application data. The demonstration project will use coal from Kentucky and West Virginia which contains 0.7 percent sulfur. Additional high sulfur coal testing will also be done. The spray dryer enhancement will be tested at the Cleveland demonstration facility (funded by the State of Ohio) to assess the ability to met NSPS requirements.

PROPOSAL 27 - SUMMARY

Proposer:	Community Central Energy Corporation
Project Title:	Fluidized-Bed Combustion of Wet Culm Fines
Project Location:	Scranton, Pennsylvania -- Lackawanna County
Technology:	Bubbling Fluidized-Bed Combustion
Application:	Industrial/Commercial
Product:	Steam
Type of Coal Used:	Anthracite Culm Waste
Project Size:	130 tons per day of culm waste
Project Starting Date:	10/01/86
Project Duration:	36 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funder: Community Central Energy Corporation

BRIEF DESCRIPTIVE SUMMARY:

The Community Central Energy Corporation proposes a project to develop a procedure to burn wet anthracite culm fines (wet silt) using a 70,000 lb/hr steam conventional bubbling fluidized-bed boiler. The site is an old steam plant in Scranton, Pennsylvania, which currently houses 10 coal-fired boilers, some of which are inactive. The project will displace No. 6 fuel oil presently used to generate steam in the District Heating System. It is anticipated that by adding limestone to the carbon fines within the fluidized-bed, the sulfur can be absorbed and that by keeping the combustion bed temperatures at between 1,400 - 1,600°F the formation of nitrogen oxides will be prevented.

The culm fines are readily available in abundant supply in Northeastern Pennsylvania as anthracite refuse generated by processing and cleaning plants and are used to a limited extent by electric generating stations. These stations blend the material with other coal for firing in pulverized coal boilers.

PROPOSAL 29 - SUMMARY

Proposer:	United Coal Company
Project Title:	Coal Waste Recovery-Advanced Technology Demonstration
Project Location:	Sharples, West Virginia -- Logan County
Technology:	Microbubble Flotation and Centrifugal Drying of Coal Preparation Wastes
Application:	Upgrading/recovering coal refuse for combustion
Product:	Beneficiated Coal
Type of Coal Used:	Low sulfur coal fines from existing impoundments
Project Size:	Identified as proprietary
Project Starting Date:	10/01/86
Project Duration:	24 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funder: United Coal Company

BRIEF DESCRIPTIVE SUMMARY:

The United Coal Company of Bristol, Virginia, will demonstrate the recovery of fine, low sulfur coal from the Monclo Refuse Disposal impoundment. The waste material slurry in the impoundment will be removed using a Mudcat floating dredge. It will be pumped to Flotaire microbubble flotation cells where the fine coal will be efficiently separated from the ash. The recovered coal will then be dried to 7.7 percent moisture content using a Robert and Shaefer centrifuge. The final product is a low ash, low sulfur coal in a granular, non-dusty form. It is easy to handle, and suitable for blending. The demonstration project will encompass a two year period and will be conducted at the Sharples Coal Facility, Logan County, West Virginia.

PROPOSAL 30 - SUMMARY

Proposer: Dravo Wellman Company

Project Title: Commercialization of Battelle Treated Coal (BTC)

Project Location: To be determined

Technology: Gasification of Battelle treated coal

Application: Substitute fuel replacing oil and natural gas

Product: Fuel gas low in sulfur and without tar

Type of Coal Used: High sulfur bituminous (Ohio #6)

Project Size: 70 MM Btu per hour

Project Starting Date: 09/01/86

Project Duration: 42 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
51	49

Proposed Co-Funders: Dravo Wellman Company
Battelle Columbus
State of Ohio

BRIEF DESCRIPTIVE SUMMARY:

Advanced development, including pilot plant testing and commercial demonstration of a coal catalyzation system has been proposed by Dravo Wellman Company in conjunction with Battelle Columbus Laboratories.

Coal/lime agglomeration produced by the proprietary Battelle treated coal (BTC) process is gasified so as to produce a low-Btu fuel gas low in sulfur, without tars and having a significantly higher heating value than is proposed from untreated coal. Total gas output of the gasification facility will be burned in the users boiler. There will be minimal emissions from the gasification plant. The major purpose of this proposal is to demonstrate the economic viability of this BTC process by constructing a commercial plant and operating it to obtain cost as well as technical data.

PROPOSAL 31 - SUMMARY

Proposer:	Sanitech, Inc.
Project Title:	Demonstration of DOE-Sanitech Traveling Grate Coal Gasification Process
Project Location:	Hamilton, Elyria, Ohio -- Butler/Lorain County
Technology:	Surface Gasification
Application:	Utility, Industry
Product:	
Type of Coal Used:	Ohio high sulfur
Project Size:	100 mmBtu/hr and 30 mmBtu/hr
Project Starting Date:	10/01/86
Project Duration:	36 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders: Sanitech, Inc.
City of Hamilton, Ohio
Lorain County Community College
Ohio Coal Development Office

BRIEF DESCRIPTIVE SUMMARY:

The process uses an atmospheric pressure gasifier in which coal is supplied to one end of a horizontal, continuously-moving grate and low-Btu fuel gas and ash are removed separately at the opposite end. Prior to gasification, the coal feedstock is crushed, mixed with limestone, and formed into pellets. With this procedure, essentially all the sulfur can be retained in the ash and no downstream sulfur removal equipment is required. This allows production of an almost sulfur-free fuel gas from coals with high sulfur content in a low cost system. This is the key advantage of the technology. The gasification technology was developed under DOE sponsorship and tested at the pilot scale. The proposed project will demonstrate the gasification technology on a larger scale and will include combustion of the hot fuel gas at two sites. At the Hamilton facility, 100 million Btu/hr of gas will be produced on a circular-grate version of the gasifier and will be used as supplementary fuel for an existing coal-fired boiler. At the Lorain facility, 30 million Btu/hr gas will be produced on a straight-grate gasifier and will be burned to generate steam for building heat.

PROPOSAL 32 - SUMMARY

Proposer:	Community Central Energy Corporation
Project Title:	Community Central Energy Corporation Clean Coal Technology Project
Project Location:	Scranton, Pennsylvania -- Lackawanna County
Technology:	Advanced Physical Coal Cleaning
Application:	Industrial and commercial boilers and process heaters
Product:	Cleaned coal/steam
Type of Coal Used:	Anthracite and Eastern high sulfur, high ash bituminous
Project Size:	Boiler -- 100,000 lbs of steam per hour derated to 60,000 lbs/hour steam; Coal preparation plant -- 5 tons/hour coal output
Project Starting Date:	01/01/87
Project Duration:	26 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50.5	49.5

Proposed Co-Funder: Community Central Energy Corporation

BRIEF DESCRIPTIVE SUMMARY:

The process uses an atmospheric pressure gasifier in which coal is supplied to one end of a horizontal, continuously-moving grate and low-Btu fuel gas and ash are removed separately at the opposite end. Prior to gasification, the coal feedstock is crushed, mixed with limestone, and formed into pellets. With this procedure, essentially all the sulfur can be retained in the ash and no downstream sulfur removal equipment is required. This allows production of an almost sulfur-free fuel gas from coals with high sulfur content in a low cost system. This is the key advantage of the technology. The gasification technology was developed under DOE sponsorship and tested at the pilot scale. The proposed project will demonstrate the gasification technology on a larger scale and will include combustion of the hot fuel gas at two sites. At the Hamilton facility, 100 million Btu/hr of gas will be produced on a circular-grate version of the gasifier and will be used as supplementary fuel for an existing coal-fired boiler. At the Lorain facility, 30 million Btu/hr gas will be produced on a straight-grate gasifier and will be burned to generate steam for building heat.

PROPOSAL 33 - SUMMARY*

Proposer:	Atlantic Research Corporation
Project Title:	Atlantic Research Corporation Clean Coal Demonstration Project
Project Location:	Identified as proprietary
Technology:	Microbial/Advanced Physical Coal Cleaning
Application:	New and retrofit utility, industrial boiler and commercial/residential sectors
Product:	Clean coal
Type of Coal Used:	Upper Freeport - Western Pennsylvania, high volatile bituminous; Kentucky #9 - high volatile bituminous; an Ohio coal
Project Size:	24 ton/day cleaned coal output
Project Starting Date:	09/01/86
Project Duration:	20 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders:

Atlantic Research Corporation
EPRI
State of Ohio
Dayton Power and Light
Pennsylvania State University
Houston Lighting and Power
Boston Edison Company
Consolidated Edison
Baltimore Gas and Electric
Pyro Mining Company .

* This proposal was withdrawn from consideration at the request of the offeror.

BRIEF DESCRIPTIVE SUMMARY:

The project will demonstrate the commercial viability of desulfurizing coal using microbial action. A one ton-per-hour demonstration plant will be constructed and operated by Atlantic Research Corporation.

Specific technical goals of the project are the cleaning of a medium sulfur Northern Appalachian coal to less than 0.6 lb SO_2/mmBtu and high sulfur Midwestern bituminous coals to less than 1.2 lb SO_2/mmBtu (when combusted). These goals will be realized by processing coal using two types of microbes to remove both organic and pyritic sulfur. The organic-sulfur-degrading micro-organism was derived from a naturally occurring soil microbe. The pyrite-modifying microbe is also naturally occurring.

In the demonstration plant, pyritic sulfur will be removed from coal by the ARC's Microbially Augmented Ash and Pyrite Physical Separation (MAAPS) process. The process utilizes a microbe to change the surface properties of the pyrite and ash to facilitate the separation of these impurities. Organic sulfur will be removed from coal using Atlantic Research Corporation's patented microbe, CB1. This micro-organism has been engineered to selectively oxidize the major organic sulfur form (thiophenic sulfur) in coal to a water soluble sulfate which can be washed from coal.

PROPOSAL 34 - SUMMARY

Proposer:	Energy and Environmental Research Corporation
Project Title:	Gas Reburning/Sorbent Injection
Project Location:	Bartonville, Illinois -- Peoria County Hennepin, Illinois -- Putnam County Springfield, Illinois -- Sangamon County
Technology:	Flue gas cleanup by gas reburning for NO_x control and sorbent injection (LIMB) for SO_x control.
Application:	Utility, industrial boilers--retrofits
Product:	Environmental control technology
Type of Coal Used:	Illinois bituminous
Project Size:	117 MWe, 80 MWe, 40 MWe boilers (three sites)
Project Starting Date:	01/01/87
Project Duration:	48 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders: Gas Research Institute
State of Illinois

BRIEF DESCRIPTIVE SUMMARY:

The EER Corporation in conjunction with the Gas Research Institute and the State of Illinois proposes to demonstrate a combination of gas reburning and sorbent injection for the control of SO_2 and NO_x emissions from existing coal-fired boilers. Program goals are 60 percent NO_x control and 50 percent SO_2 control. Reburning is achieved by injection of natural gas (10 to 20 percent of the total fuel input) above the normal furnace heat release zone to produce an oxygen deficient region in the upper furnace (reburning zone). Burnout air is introduced above the reburning zone to complete the fuel combustion. A portion of the NO_x produced in the main heat release zone is decomposed to molecular nitrogen in the reburning zone. Since the reburning fuel contains no sulfur, SO_2 emissions are reduced in proportion to the amount of gas fired. Additional SO_2 emission reductions are obtained by injection of calcium based sorbents either with the burnout air or downstream between the air preheater and the electrostatic precipitator.

Three host sites have been selected representing the three major firing configurations currently employed. These are tangential (Hennepin site), wall fired (Bartonville site), and cyclone (Springfield site). Boiler sizes are 80 MWe, 117 MWe, and 40 MWe, respectively. A 48-month program is proposed with a 60 month period required if phase overlap is omitted.

PROPOSAL 35 - SUMMARY

Proposer:	Curators of the University of Missouri
Project Title:	200,000 PPH MSFBC Boiler Project
Project Location:	Columbia, Missouri -- Boone County
Technology:	Multi-solid circulating fluidized-bed combustion
Application:	Commercial, industrial
Product:	Steam power generation
Type of Coal Used:	Sub-bituminous/high sulfur
Project Size:	200,000 pounds/hour of steam
Project Starting Date:	10/01/86
Project Duration:	12 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
95.7	4.3

Proposed Co-Funders: Curators of the University of Missouri

BRIEF DESCRIPTIVE SUMMARY:

The objective of this project is to increase the University of Missouri Campus Power Plant's steam and electric power generation capacity. The Battelle multi-solid fluidized-bed combustion system is the unit that will be installed in the existing Campus Power Plant in an area previously planned for a new boiler. Major improvements are scheduled for completion and commercial operation by October 1987. The project will use a 200,000 pph coal-fired atmospheric multi-solid circulating fluidized-bed boiler to generate steam. The boiler will burn a high sulfur coal from central Missouri with a heat content of approximately 11,000 Btu per pound.

PROPOSAL 36 - SUMMARY

Proposer:	Coal Technology Corporation
Project Title:	Advanced Clean Coal Technology in Secondary Recovery
Project Location:	Luzerne Township, Pennsylvania -- Fayette County
Technology:	Physical Benefication of Coal Mining Wastes
Application:	Upgrading coal refuse for combustion
Product:	Cleaned coal
Type of Coal Used:	Pittsburgh
Project Size:	1,000 tons/day
Project Starting Date:	06/30/86
Project Duration:	20 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funder: Coal Technology Corporation

BRIEF DESCRIPTIVE SUMMARY:

Aside from utilizing conventional commercially available coal processing equipment, the Coal Technology Corporation proposes to use part of the very fine, high density magnetite particles normally contained in the refuse pile to increase the density of the water slurry used in a hydrocyclone separator to separate the coal from the muck and mineral fragments. The hydrocyclone operates on the principle of using a water flotation process to separate the lighter coal fraction from the heavier muck, rock, and mineral fraction. A system of fine screens will be used to separate the magnetite so it can be recirculated in the process instead of being discharged in the wastewater stream along with the muck and slimes fraction of the refuse pile. A Phoenix belt filter press utilizing a static flocculant mixing device is used for dewatering the coal product.

The proposed project would purchase equipment, construct facilities, and operate to recover coal from a particular waste site in Pennsylvania.

PROPOSAL 37 - SUMMARY

Proposer:	Ztek Corporation
Project Title:	Directly Integrated Power Plant Using Solid Oxide Fuel Cells with Gasifier
Project Location:	Not identified
Technology:	Planar solid oxide fuel cell system
Application:	Utility power generation; commercial and industrial cogeneration
Product:	Electricity
Type of Coal Used:	Unrestricted
Project Size:	50 kW solid oxide fuel cell module
Project Starting Date:	1986
Project Duration:	72 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders: ZTEK Corporation
Electric Power Research Corporation

BRIEF DESCRIPTIVE SUMMARY:

This proposal is for the development of a solid oxide (zirconia) fuel cell module for eventual integration into coal gasifiers. Work proposed addresses the design of the fuel cell device itself and proposes to test the power generating module, utilizing a host facility to be determined at a later date which will provide the gasifier or gasifier-like combustion environment.

Some of the advantages of this integrated system as proposed and conceptualized by ZTEK are: reasonable capital costs, busbar costs about 20 percent below a new conventional coal-fired steam system, and mutually compatible operating requirements (gasifier/fuel cells).

PROPOSAL 38 - SUMMARY

Proposer:	Coal Tech Corp.
Project Title:	Advanced Cyclone Combustor Demonstration
Project Location:	Williamsport, Pennsylvania -- Lycoming County
Technology:	Advanced Air-Cooled Slagging Cyclone Combustor with Limestone Addition for SO_2 Control
Application:	Industrial and Utility Boilers; New or Retrofit; Coal, Oil, or Gas Designed
Product:	Steam and/or electricity
Type of Coal Used:	Utah Black Mesa Sub-bituminous, Pennsylvania Bituminous - Freeport Seam (2-4%S)
Project Size:	1 ton/hr coal feed to combustor
Project Starting Date:	10/01/86
Project Duration:	27 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders:
Coal Tech Corp.
Pennsylvania State Energy Development Authority
Southern California Edison
Pennsylvania Power and Light
Keeler Boiler Manufacturing Company

BRIEF DESCRIPTIVE SUMMARY:

The proposed project is for a 1,000 hour test to demonstrate the performance of an advanced, air-cooled, cyclone combustor with dry pulverized coal. Two Pennsylvania bituminous coals, containing 2 percent and 3 to 4 percent sulfur, and one Utah sub-bituminous coal, containing 0.5 percent sulfur, will be combusted to demonstrate that this advanced combustor is capable of burning a variety of United States' coals in an environmentally acceptable manner. The technical performance objectives of the proposed project are to demonstrate: (1) 90 to 95 percent coal ash retention in the combustor (and subsequent rejection), (2) NO_x reductions to 100 ppm or less, (3) sulfur oxide emission reductions of 70 to 90 percent, and (4) combustor durability and flexibility.

The combustor can be adapted to retrofit boilers as well as new; it can be used for converting oil and gas designed boilers to coal; and it has industrial and utility applications.

The Coal Tech Corp. is now constructing a 30 MBtu/hr (1 ton/hr) combustor which is nearing completion. The proposed demonstration project will be conducted at the Keeler Boiler Company/Dorr Oliver, Williamsport site, Pennsylvania, where a 23 MBtu/hr D-tube package boiler designed for oil is available. The demonstration will conclude in 27 months.

PROPOSAL 39 - SUMMARY

Proposer:	Southwestern Public Service Company
Project Title:	Circulating Fluid-Bed Repowering
Project Location:	Amarillo, Texas -- Potter County
Technology:	Circulating Fluidized-Bed Combustion
Application:	Utility
Product:	Electricity
Type of Coal Used:	Western bituminous
Project Size:	250 MWe
Project Starting Date:	08/01/86
Project Duration:	100 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
62	38

Proposed Co-Funder: Southwestern Public Service Company

BRIEF DESCRIPTIVE SUMMARY:

Southwestern Public Service Company (SPS), an electric utility based in Amarillo, Texas, is planning to replace an existing 18-year old, gas-fueled power plant boiler with a circulating fluidized-bed coal-fired boiler. The steam will drive the existing 250 MW Unit No. 3 steam turbine generator at SPS' Nichols Station, located near Amarillo.

The CFB boiler combines two new desirable operating features (i.e., in-furnace pollutant control and fuel source flexibility). First the oxides of sulfur (SO_x), normally released when coal is burned, are captured in the CFB furnace. CFB's typically operate at approximately 1,600°F to optimize the limestone-SO_x reaction. This temperature is below that at which significant amounts of NO_x are formed. The CFB's second major advantage, fuel flexibility, permits more competitive fuel sourcing.

The prime coals planned for this project are bituminous coals from New Mexico, Wyoming, and Oklahoma. The coals will be tested to demonstrate the flexibility of the CFB. The new boiler will be twice as large as the largest CFB currently under construction.

PROPOSAL 40 - SUMMARY

Proposer:	Recovery Systems Limited
Project Title:	Demonstration of Post Combustion Cleanup Process for Combined SO_x/NO_x Removal From Flue Gases Resulting in Commercially Valuable Phosphate Fertilizer
Project Location:	One of three candidate sites in the midwest U.S. Yet To Be Determined Hennepin, Illinois -- Putnam County Fayette, Indiana -- Vigo County Cassiville, Wisconsin -- Grant County
Technology:	Post combustion cleanup
Application:	Large capacity coal-fired electric utility plants firing high sulfur coal
Product:	Electricity
Type of Coal Used:	Technology is most applicable for use with high sulfur coal
Project Size:	100 MW
Project Starting Date:	01/02/87
Project Duration:	38 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funder: Recovery Systems Limited

BRIEF DESCRIPTIVE SUMMARY:

The Pircon-Peck process captures sulfur and nitrogen oxides from high sulfur coal-fired power plant stack gases and simultaneously manufactures agricultural phosphate fertilizers. The process uses phosphate rock and ammonia, major raw materials for conventional high potency fertilizer manufacture, as chemical reagents that enable high efficiency removal of acid gases, such as SO_2 and nitric oxide, from stack discharges. By this choice of reagent alkali, the acid gases being collected can effectively be substituted for the costly manufactured acid typically used in the conversion of phosphate rock to a useable fertilizer form. The resulting reaction byproduct is ammonium phosphate fertilizer. The demonstration project will establish an initial large scale operation to prove the practicality and commercial attractiveness of such installations, both as efficient air pollution control systems and as significant producers of fertilizer products commonly used for midwestern crop production.

PROPOSAL 41 - SUMMARY

Proposer:	PPG Industries, Inc.
Project Title:	Phosphoric Acid Fuel Cell System Using Coal-Derived Gas
Project Location:	Lake Charles, Louisiana -- Calcasieu County
Technology:	Power generation based upon a phosphoric acid fuel cell fueled by hydrogen
Application:	Industrial and utility sources of electrical energy
Product:	Direct electrical current
Type of Coal Used:	Not applicable to this project
Project Size:	375 kWe
Project Starting Date:	09/02/86
Project Duration:	72 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funder: PPG Industries, Inc.

BRIEF DESCRIPTIVE SUMMARY:

The proposed project calls for the design, construction, and operation of a phosphoric acid fuel cell system to generate electrical power. A fuel cell is an electrochemical device which converts the chemical energy of a fuel (e.g., hydrogen) and oxidant (e.g., oxygen in air) directly to usable electrical energy and heat without combustion as an intermediate step. A fuel cell system sized at 375 kilowatts of direct electrical current (dc) will be constructed as a semi-works facility, which is proposed as the smallest repeating modular unit of a commercial-sized fuel cell plant. The proposed fuel cell demonstration will be fully integrated with a chlorine/caustic production plant owned and operated by PPG Industries at Lake Charles, Louisiana. The 375 kWe of dc power generated from the fuel cell will be used in existing industrial chlor-alkali electrolyzers which produce chlorine and caustic soda for commercial markets; byproduct hydrogen produced from the electrolyzer will be used as the fuel source for the proposed phosphoric acid fuel cell demonstration.

This demonstration facility would represent an application of a fuel cell power plant to an industrial operation. Although coal is not proposed for use in the demonstration project, commercial applications of the proposed fuel cell technology are projected to utilize fuel hydrogen produced from gasification of coal with subsequent cleaning and processing of the gas into hydrogen. The proposed phosphoric acid fuel cell (PAFC) system to be demonstrated is based upon the PAFC technology developed by Energy Resource Corporation and marketed by Westinghouse Electric Corporation.

PROPOSAL 42 - SUMMARY

Proposer:	McDonnell Douglas Energy Systems, Inc.
Project Title:	Advanced Physical Coal Cleaning Technology (Microbubble Flotation)
Project Location:	Shelbyville, Kentucky -- Shelby County
Technology:	Advanced microbubble flotation coal cleaning process
Application:	Utilities, industrial boilers, waste stream product recovery at coal preparation plants
Product:	Clean Coal
Type of Coal Used:	Pittsburgh #8, Kentucky #9, Upper Freeport
Project Size:	5 tph clean coal output
Project Starting Date:	10/01/86
Project Duration:	45 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funder: McDonnell Douglas Energy Systems, Inc.

BRIEF DESCRIPTIVE SUMMARY:

The objective of this project is to demonstrate the commercial feasibility of an applied clean coal technology employing microbubble column flotation as a means for physically removing inorganic sulfur and ash-forming mineral matter from bituminous coal deposits. The project will involve the construction and operation of a 5 ton/hour advanced coal cleaning plant to be located in Shelbyville, Kentucky.

The proposed microbubble column flotation technology utilizes microbubbles in a vertical flotation column containing a dilute mixture of pulverized coal and water to separate the lighter fraction of coal particles from the heavier, more dense ash impurities. A resulting froth containing the purified coal rises to the top of the column where it is collected and subsequently treated and dewatered for possible use as a coal slurry fuel or further processed into a pelletized form for use in a variety of possible combustion applications. The process represents an improvement over conventional flotation in maximizing efficient removal of the inorganic pyritic sulfur and major portions of the ash impurities.

PROPOSAL 43 - SUMMARY

Proposer:	Westinghouse Electric Corp.
Project Title:	Clean Coal Fuel Cell Technology Program
Project Location:	Madison, Pennsylvania -- Westmoreland County
Technology:	KRW Coal Gasifier and Cleanup Sub System Integrated with a Phosphoric Acid Fuel Cell Power Plant
Application:	Integrated plants for electric utility and industrial cogeneration
Product:	Electricity
Type of Coal Used:	Wyoming sub-bituminous - C, Pittsburgh No. 8, North Dakota lignite, upper Kittanning bituminous
Project Size:	1.5 MWe from the fuel cell (four 0.375 MWe stacks); 1/2 to 3/4 ton coal per hour feed
Project Starting Date:	09/01/86
Project Duration:	50 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
63.7	36.3

Proposed Co-Funders: Electric Power Research Institute
ESEERCO

BRIEF DESCRIPTIVE SUMMARY:

The proposed Clean Coal Fuel Cell Demonstration Project would take advantage of two DOE supported technology development programs to demonstrate the technical, environmental, and economic advantages of commercial coal gasification fuel cell power plants in the 25 to 75 MW market. Westinghouse and its sponsoring utility organizations propose to make available the DOE developed 1.5 MWe fuel cell pilot power plant for integration with the existing DOE/KRW gasification PDU resulting in a first-of-a-kind demonstration of a coal gas-fired fuel cell power system. Since the PDU will be dedicated to the demonstration project, the composition of the coal and gas can be adjusted to verify proper fuel cell operation. The proposed system will provide a demonstration of the feasibility, performance, emissions, and operation of the use of coal-derived gas in a phosphoric acid fuel cell so that scale-up to a 7.5 MWe prototype commercial plant can be built.

PROPOSAL 44 - SUMMARY

Proposer:	ChemCoal Associates
Project Title:	ChemCoal Process Technology
Project Location:	Powhatan Point, Ohio -- Monroe County
Technology:	Liquefaction
Application:	Principally utility, industrial, transportation application as distillate extender for marine, railroad, and stationary diesel engine, and feedstock for petroleum refineries.
Product:	"SRC-I type" product
Type of Coal Used:	Ohio #8 and #6 North Dakota Lignite
Project Size:	10 tpd coal
Project Starting Date:	09/01/86
Project Duration:	48 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders: ChemCoal Associates
Carbon Resources Inc.
North American Coal Corporation
State of Ohio

BRIEF DESCRIPTIVE SUMMARY:

This project will demonstrate the ChemCoal Process Technology, which produces clean coal products, at a 10-tons-per-day Demonstration Plant using primary Ohio No. 8 and No. 6 coals at a facility near Powhatan Point, Ohio.

The ChemCoal process uses a chemical method to transform coal and other carbonaceous materials into clean solid and liquid products. The process uses coal-derived solvents and aqueous alkali to dissolve and breakdown the organic carbonaceous fraction of the coal. The sulfur and ash are then separated from the dissolved organic fraction. The process yields high quality solid and distillate products. Technical objectives include production of high quality marketable carbonaceous materials in solid, liquid, and slurry form from U.S. coals. Quality objectives for ChemCoal solid products are: 1) 0.8 percent or less total sulfur, 2) 0.3 percent or less ash, 3) 15,000 Btu/lb or more, and 4) 100 percent minus 20 micron paricle size. The quality objectives assume a 11,500 Btu/lb feed coal with 3-1/2 percent total sulfur and 10 percent ash.

Targeted market applications are: 1) distillate extender for marine and railroad diesel engines, 2) distillate extender for low and medium speed stationary diesel engines, 3) fuel for gas turbine combined-cycle and cogeneration industrial and electrical power plants, 4) distillate extender for domestic and commercial heating and boilers, 5) clean fuel for steam and power generating, and 6) petroleum refineries.

PROPOSAL 45 - SUMMARY

Proposer: Tennessee Valley Authority

Project Title: Lime Spray Dryer Dry Flue Gas

Project Location: Paducah, Kentucky -- McCracken County

Technology: Lime Spray Dryer/Baghouse

Application: Utility

Product: Environmental Control Technology

Type of Coal Used: Bituminous (medium to high sulfur)

Project Size: 160 MW

Project Starting Date: 01/01/87

Project Duration: 47 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders: Tennessee Valley Authority
General Electric Environmental Services Inc.

BRIEF DESCRIPTIVE SUMMARY:

In the lime spray dryer dry flue gas desulfurization (DFGD) process being proposed, hot flue gas enters a cylindrical, conical-bottom spray dryer vessel within which an atomized slurry of slaked lime and recycle solids contacts the gas stream. The sulfur oxides react with the alkaline lime to form calcium sulfite and sulfate precipitates. The particulate waste material containing about 1 percent water and flyash is removed in the spray dryer cone and in a downstream baghouse. The balance of the slurry water vaporizes and is emitted with the scrubbed gas. This technology is presently in commercial service on low sulfur Western coals.

TVA with General Electric Environmental Services, Inc., acting as principal subcontractor proposes to design, construct, and demonstrate a full-scale DFGD system to provide the data required to confirm the ability to adequately treat flue gas from medium- to high-sulfur coals under a variety of boiler operating conditions to provide the essential design and operating parameters required to establish the process as a viable commercial alternative for high sulfur coal applications. A full-scale system utilizing an existing baghouse will be retrofitted to the 160 MW Unit No. 8 boiler at TVA's Shawnee plant near Paducah, Kentucky. Construction would be followed by a 24 month demonstration program to evaluate system performance over a range of conditions including coals containing up to 4.5 percent sulfur (dry basis).

PROPOSAL 46 - SUMMARY

Proposer:	Questar Synfuels Corporation
Project Title:	Utah Clean Coal Project
Project Location:	West Jordan, Utah -- Salt Lake County
Technology:	Gasification Combined Cycle
Application:	Small Scale Power Production; Industrial Cogeneration
Product:	Electricity, Methanol
Type of Coal Used:	Utah bituminous, Wyoming sub-bituminous, Eastern high sulfur bituminous
Project Size:	30 tons coal/day
Project Starting Date:	07/01/86
Project Duration:	48 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funder: Questar Synfuels Corporation

BRIEF DESCRIPTIVE SUMMARY:

An existing coal gasification process development unit will be modified and upgraded for processing 30 tons of bituminous coal per day. The gasifier is an oxygen-blown entrained gasifier with dry coal feed. New equipment for scrubbing particulates and sulfur from the product gas will be installed. New facilities will be constructed for producing up to 2.3 megawatts of net electric power from a steam turbine using steam from a process heat recovery system and from a reciprocating engine burning the clean fuel gas. Equipment will also be installed for demonstrating the conversion of the synthesis gas to methanol via a new catalytic process being developed by Brookhaven National Laboratory. The project will consist of a 6-month design phase, a 24-month construction and startup phase, and an 18-month operations phase.

PROPOSAL 47 - SUMMARY

Proposer:	Tennessee Valley Authority
Project Title:	Once-Through Methanol Project
Project Location:	Muscle Shoals, Alabama -- Colbert County
Technology:	Indirect Liquefaction/Once-Through Methanol/IGCC
Application:	Principally utility as proposed (but the methanol produced could have broad market applications)
Product:	Methanol/electricity
Type of Coal Used:	Appalachian region bituminous: Warrior Field, Alabama; Pittsburgh Seam (Ohio and Pennsylvania); Interior eastern region: Illinois (in Illinois and western Kentucky)
Project Size:	200 tpd coal gasifier to produce up to 35 tpd of methanol product and a medium-Btu gas byproduct for use as boiler fuel
Project Starting Date:	10/01/86
Project Duration:	41 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders: Tennessee Valley Authority
Air Products and Chemicals Inc.
Electric Power Research Institute
Southern California Edison
Electric Power Development Company (Japan)

BRIEF DESCRIPTIVE SUMMARY:

A once-through methanol synthesis process is proposed to be integrated with coal gasification to demonstrate a technology that can be used for a load following/energy storage capability. The primary focus of the project is demonstration of liquid-phase methanol technology. A powdered methanol synthesis catalyst is entrained in an inert circulating oil as a slurry in a reactor where the methanol is produced from reaction of the hydrogen/carbon monoxide. In the commercial version, the unreacted tail gas will be combusted and expanded through a turbine and liquid methanol will be stored for peaking applications. The existing Texaco gasifier at TVA's site will provide the synthesis gas and the existing gas cleanup system will be modified. A once-through methanol system will be added.

Tail gas will be used in the boiler (a gas turbine is not included as part of the project). Gas-phase methanol synthesis will also be tested on a slip stream of co-rich synthesis gas.

PROPOSAL 48 - SUMMARY

Proposer:	General Electric Company
Project Title:	Integrated Gasification-Steam Injected Gas Turbine
Project Location:	Evendale, Ohio -- Hamilton County Dunkirk, New York -- Chautauqua County
Technology:	IG-STIG with Hot Gas Cleanup
Application:	Utility, Industrial
Product:	Electricity, steam
Type of Coal Used:	Eastern Bituminous
Project Size:	50 MW and 5 MW
Project Starting Date:	01/02/87
Project Duration:	60 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funders:
General Electric Company
Niagra Mohawk Power Corporation
Peabody Holding Company
Burlington Northern Railroad
Ohio Department of Development
Empire State Electrical Energy Research Corporation
New York Energy Research and Development Authority

BRIEF DESCRIPTIVE SUMMARY:

The project will use an integrated coal gasification, steam-injected gas turbine power plant to demonstrate the feasibility of simplified gasification systems for commercial coal-to-electricity applications. The simplified system is configured to reduce components in each of the major subsystems; gasification; gas cleanup, and gas turbine power generation system, while retaining commercial hardware and design philosophy for many of the subsystem components. The technology uses an air-blown moving bed gasifier, zinc-ferrite sulfur removal technology, hot cyclones, and the "LM" series (aircraft derivative) gas turbine/generator package. Key elements are the high-temperature gas cleanup systems which can allow significant reduction in the contaminant levels without degradation of plant efficiency. The system will be demonstrated at different sizes at the 2 site locations; a 5 MW plant at the Dunkirk Station of the Niagara Mohawk Power Corporation and a 50 MW plant at the General Electric Evandale Plant.

PROPOSAL 49 - SUMMARY

Proposer:	FMC Corporation
Project Title:	Dry Injection Flue Gas Desulfurization Test Program
Project Location:	New Richmond, Ohio -- Clermont County
Technology:	Flue gas cleanup
Application:	Utility
Product:	Environmental control technology
Type of Coal Used:	Medium to high sulfur coal (some data will be taken with low sulfur coal)
Project Size:	To be tested on a 100 MW boiler
Project Starting Date:	TBD
Project Duration:	2 months test

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
67	33

Proposed Co-Funders: FMC Corporation
State of Ohio
Cincinnati Gas and Electric Company

BRIEF DESCRIPTIVE SUMMARY:

The proposed project is to accomplish the removal of sulfur dioxide and nitrogen oxides by injecting dry sodium compounds into the flue gas upstream of an ESP and to show that at least 50 percent SO_2 removal can be economically achieved while burning medium to high sulfur coal. Sulfur dioxide and nitrogen oxides react with the dry sodium sorbent both while it is entrained in the flue gas stream and after it has been captured in the particulate collection device. The affect of sodium injection on the operation and performance of the ESP will also be studied. Both spent sorbent and flyash are removed in the normal manner from the hoppers of the collection device.

PROPOSAL 51 - SUMMARY

Proposer:	National Lime Association
Project Title:	No specific project title was furnished by Offeror
Project Location:	Not applicable
Technology:	Not applicable
Application:	Not applicable
Product:	Not applicable
Type of Coal Used:	Not applicable
Project Size:	Not applicable
Project Starting Date:	Not applicable
Project Duration:	Not applicable
Cost Sharing:	Not applicable

Average Participant Share (%)	Average DOE Share (%)

Proposed Co-Funder: Not applicable

BRIEF DESCRIPTIVE SUMMARY:

The respondent did not submit a complete proposal for financial assistance support under the Clean Coal Technology solicitation. The intent of the National Lime Association in responding to the solicitation with a "Prospectus" rather than a formal proposal was "not to propose or enter into a minimum cost-sharing arrangement with the Department of Energy." Rather, the purpose of their proposal was "to promote knowledge concerning the use of lime in the Clean Coal Technology Program." Their intent was "to provide guidance and consultation where a lime system will be installed for the treatment of an acidic waste." Furthermore, the National Lime Association "is not requesting funds for services as consultants."

PROPOSAL 52 - SUMMARY

Proposer:	Chemion Corporation
Project Title:	Coal Dusulfurization Project
Project Location:	Mobile Facility
Technology:	Coal preparation
Application:	Upgrading of coal quality by eliminating all SO_X and NO_X compounds
Product:	Coal
Type of Coal Used:	Lignite, bituminous, and sub-bituminous
Project Size:	5 tons/per hour
Project Starting Date:	5/1/86 - 8/15/86
Project Duration:	24 months

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
50	50

Proposed Co-Funder: Chemion Corporation

BRIEF DESCRIPTIVE SUMMARY:

The process is described as a chemical extraction that treats pulverized coal. The chemical composition of the solvent is not given except to say that it is non-flammable and mildly toxic. The proposer claims to have a laboratory demonstrated coal cleaning process that can achieve a 100 percent removal of all organic and inorganic sulfur contained in samples of coal acquired from diverse deposits across the United States. These include specimens of lignite, bituminous, and sub-bituminous coals in highly contaminated conditions.

Claims for the process also include achieving a 100 percent removal of all nitrogenous compounds imbedded in the coal samples.

The proposed demonstration plant is envisioned as a mobile production facility capable of handling 5 tons of coal/hour in a continuous flow process. The mobile plant, used as a marketing demonstration tool, would visit and conduct extensive tests at a minimum of 17 prospective power-utility customers' locations in its first two years of operation. Priority will be given to companies situated east of the Rocky Mountains.

PROPOSAL 53 - SUMMARY

Proposer:	Charwill
Project Title:	SO_x and NO_x Removal System and Byproduct Recovery System
Project Location:	Not identified by Offeror
Technology:	Wet scrubbing of stack gases with a borate solution for sulfur and nitrogen oxides reduction, and with associated production of marketable byproducts.
Application:	Coal-fired utility generating stations
Product:	Environmental Control Technology
Type of Coal Used:	Eastern bituminous
Project Size:	Not defined
Project Starting Date:	Not defined
Project Duration:	Not defined

Cost Sharing:

Average Participant Share (%)	Average DOE Share (%)
Not Given	Not Given

Proposed Co-Funder: Charwill

BRIEF DESCRIPTIVE SUMMARY:

The proposed project calls for the application of a novel flue gas treatment process to an existing coal-fired boiler. Under the proposed project a site would be selected which contains existing flue gas scrubber and baghouse collection equipment. This existing scrubber system would be equipped with appropriate mixing system to inject a saturated solution of sodium sorbate into the flue gas for removal of both sulfur and nitrogen oxides. Equipment and procedures would be added and instituted at the facility to handle aqueous discharges associated with use of the borate scrubbing system. Additional chemical additives are to be employed in the handling of the aqueous stream to produce solid byproducts (e.g., road salt, fertilizer, etc.). Sodium borate is regenerated and recycled to the scrubber.